VFA
nstitution

INSTITUTION

OF

MECHANICAL ENGINEERS.

PROCEEDINGS.

1855.

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1855.

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LIST OF MEMBERS.

1855.

Adams, William Alexander, Midland Works, Birmingham.
Addenbrooke, George, Rough Hay Furnaces, near Darlaston.
Addison, John, 3, Delahay Street, Westminster.
Adkins, Francis, Heath Lead Works, near Birmingham.
Allan, Alexander, Scottish Central Railway, Perth.
Ashbury, John, Railway Carriage and Wheel Manufactory, Openshaw, near Manchester.

Bagnall, William, Gold's Hill Iron Works, Westbromwich.
Baker, William, London and North Western Railway, Euston Station, London.
Barwell, William Harrison, Eagle Foundry, Northampton.
Beasley, Joseph, District Iron Works, Smethwick.
Beattie, Joseph, London and South Western Railway, Locomotive Department, Nine Elms, London.
Bennett, Peter Duckworth, Spon Lane Foundry, Westbromwich.
Beyer, Charles, Messrs. Beyer, Peacock, and Co., Gorton, near Manchester.
Birley, Henry, Didsbury, near Manchester.
Blackwell, Samuel Holden, Russell's Hall Iron Works, near Dudley.
Bovill, George Hinton, Messrs. Swayne and Bovill, 19, Abchurch Lane, London.
Bragge, William, Imperial Petropolis Railway, Rio Janeiro.
Bramwell, Frederick Joseph, 29, New Bridge Street, Blackfriars, London.
Broad, Robert, Horseley Iron Works, near Tipton.
Brogden, Alexander, 3, Tib Lane, Cross Street, Manchester.
Brogden, Henry, Ulverstone, Cumberland.
Brown, James, Messrs. James Watt and Co., Soho Foundry, near Birmingham.
Brown, John, Atlas Steel Works, Sheffield.
Brown, John, Mining Engineer, Barnsley, Yorkshire.
Brown, Ralph, Patent Shaft Works, Wednesbury.
Buckle, William, Royal Mint, Tower Hill, London.

Cabry, Thomas, North Eastern Railway, York.
Cammell, Charles, Cyclops Steel Works, Sheffield.
Chamberlain, Humphrey, Clerkenleap, Kempsey, near Worcester.

Chellingworth, Thomas T., 25, Waterloo Street, Birmingham.
Clark, Daniel Kinnear, 11, Adam Street, Adelphi, London.
Clift, John Edward, Birmingham and Staffordshire Gas Works, Adderley Street, Birmingham.
Cochrane, Alexander Bailie, Woodside Iron Works, near Dudley.
Cochrane, John, Woodside Iron Works, near Dudley.
Coke, Richard George, Ankerbold, near Chesterfield.
Cooper, Samuel Thomas, Leeds Forge, Leeds.
Corry, Edward, 11, Adam Street, Adelphi, London.
Cowper, Charles, 20, Southampton Buildings, Chancery Lane, London.
Cowper, Edward Alfred, 35A, Great George Street, Westminster.
Cox, Samuel H. F., Lingfield Lodge, East Grinstead, Sussex.
Craig, William G., Manchester, Sheffield, and Lincolnshire Railway, Locomotive Department, Gorton, near Manchester.
Crampton, Thomas Russell, 15, Buckingham Street, Adelphi, London.
Croome, John, 137, Leadenhall Street, London.
Crosland, Robert, Union Foundry, Bradford.
Curtis, Matthew, Phœnix Works, Chapel Street, Manchester.

Daglish, Robert, Jun., St. Helen's Foundry, St. Helen's.
Dawes, George, Milton and Elsecar Iron Works, near Barnsley, Yorkshire.
Dawson, Christopher H., Low Moor Iron Works, near Bradford.
Dixon, Edward, Wilton House, Southampton.
Dodds, Thomas W., Holmes Engine Works, Rotherham.
Downing, George, Crown Iron Works, Smethwick.
Dubs, Henry, Messrs. Tayleur and Co., Vulcan Foundry, Warrington.
Duclos, Edouard de Boussois, 10, Place de la Bourse, Paris.
Dunn, Thomas, Windsor Bridge Iron Works, Manchester.

Elder, David, Vulcan Iron Works, Glasgow.
Elwell, Edward, Jun., Wednesbury Forge, Wednesbury.
England, George, Hatcham Iron Works, New Cross, Surrey.
Everitt, George Allen, Kingston Metal Works, Bordesley, Birmingham.

Fairbairn, William, F.R.S., The Polygon, Ardwick, Manchester.
Fairbairn, Thomas, Canal Street Works, Manchester.
Fairbairn, George, Canal Street Works, Manchester.
Fairbairn, William A., Canal Street Works, Manchester.
Fenton, James, Low Moor Iron Works, near Bradford.
Fernie, John, Midland Railway, Locomotive Department, Derby.
Fletcher, Edward, North Eastern Railway, Locomotive Department, Gateshead.

Forsyth, John C., North Staffordshire Railway, Stoke-upon-Trent.
Forsyth, Thomas, Messrs. Sharp, Stewart, and Co., Atlas Works, Manchester.
Fothergill, Benjamin, Queen's Chambers, 5, Market Street, Manchester.
Fowler, John, 2, Queen's Square Place, Westminster.
Fox, Sir Charles, 8, New Street, Spring Gardens, London.
Fraser, Joseph, Berkswell, near Coventry.
Froude, William, Dartington, Totness, Devonshire.

Garland, William S., Messrs. James Watt and Co., Soho Foundry, near Birmingham.
Gibbons, Benjamin, Hill Hampton House, near Stourport.
Goode, Benjamin W., St. Paul's Square, Birmingham.
Goodfellow, Benjamin, Hyde Iron Works, Hyde, near Manchester.
Gordon, Robert, Heaton Foundry, Stockport.
Green, Charles, Tube Works, Leak Street, Birmingham.

Hartree, William, Messrs. John Penn and Co., Marine Engineers, Greenwich.
Hawthorn, Robert, Messrs. R. and W. Hawthorn, Forth Banks, Newcastle-on-Tyne.
Hawthorn, William, Messrs. R. and W. Hawthorn, Forth Banks, Newcastle-on-Tyne.
Headly, James J., Eagle Works, Cambridge.
Henderson, John, London Works, near Birmingham.
Hennet, George, 24, Duke Street, Westminster.
Henson, Henry H., 43, Parliament Street, Westminster.
Hewitson, William Watson, Messrs. Kitson and Co., Airedale Foundry, Leeds.
Hickman, George Haden, Bilston Brook Furnaces, Bilston.
Hoby, James Ward, London Works, Renfrew, near Glasgow.
Hodge, Paul Rapsey, 11, Buckingham Street, Adelphi, London.
Hodgkin, John Eliot, Suffolk Works, Berkeley Street, Birmingham.
Holcroft, James, Shut End, Brierley Hill, Worcestershire.
Homersham, Samuel Collett, 19, Buckingham Street, Adelphi, London.
Horton, Joshua, Etna Works, Smethwick.
Howell, Joseph, Hawarden, Flintshire.
Hughes, John, 34, Great George Street, Westminster.
Humphrys, Edward, Messrs. Humphrys, Tennant, and Dykes, Deptford Pier, London.

Ikin, Jonathan Dickson, 2, Cannon Row, Westminster.

Jackson, Peter Rothwell, Salford Rolling Mills, Manchester.
Jee, Alfred Stanistreet, 6, John Street, Adelphi, London.
Jeffcock, Parkin, Mining Engineer, 3, Stuart Terrace, Greenhill, Derby.
Jobson, John, Litchurch Works, near Derby.
Jobson, Robert, Holly Hall Works, near Dudley.
Johns, Henry, 8, Grange Terrace, Brompton, London.

Johnson, James, Great Northern Railway, Locomotive Department, Doncaster.
Johnson, Richard William, The Laurels, Hagley Road, Birmingham.
Johnson, William, 166, Buchanan Street, Glasgow.
Johnson, William Beckett, St. George's Foundry, Minshull Street, Manchester.
Jones, Edward, 3, Grenfield Terrace, Edge Hill, Liverpool.
Joy, David, 5, Queen Square, Leeds.

Kennedy, James, 33, Erskine Street, Liverpool.
Kinmond, William L., Montreal, Canada, (and Broughty Ferry, near Dundee.)
Kirkham, John, Imperial Gas Works, 3, Tonbridge Place, Euston Square, London.
Kirtley, Matthew, Midland Railway, Locomotive Department, Derby.
Kitson, James, Airedale Foundry, Leeds.

Ledger, Thomas, 173, Aldersgate Street, London.
Lewis, Benjamin, Stanley Street Works, Salford, Manchester.
Linn, John, Jun., 14, Cumberland Terrace, Parliament Street, Liverpool.
Lloyd, George Braithwaite, Jun., Tube Works, Berkeley Street, Birmingham.
Lloyd, Sampson, Old Park Iron Works, Wednesbury.
Lloyd, Samuel, Jun., Old Park Iron Works, Wednesbury.
Lynde, James Gascoigne, 37, Great George Street, Westminster.

Macgregor, Walter F., Vauxhall Foundry, Liverpool.
Marshall, Edwin, Britannia Carriage Works, Birmingham.
Marshall, William Prime, 81, Newhall Street, Birmingham.
Marten, Henry, 19, Darlington Street, Wolverhampton.
Martineau, Francis Edgar, Globe Works, Cliveland Street, Birmingham.
Mathews, William, Corbyn's Hall Iron Works, near Dudley.
Matthew, John, Messrs. John Penn and Co., Marine Engineers, Greenwich.
Matthews, William Anthony, Sheaf Works, Sheffield.
McClean, John Robinson, 17, Great George Street, Westminster.
McConnell, James Edward, London and North Western Railway, Locomotive Department, Wolverton.
Middleton, William, Vulcan Iron Foundry, Summer Lane, Birmingham.
Miller, George M., Great Southern and Western Railway, Dublin.
Miller, Joseph, F.R.S., Oakley House, Alpha Road, St. John's Wood, London.
Morrison, Robert, Ouseburn Engine Works, Newcastle-on-Tyne.

Napier, John, Vulcan Iron Works, Glasgow.
Nixon, Charles, 26, Great George Street, Westminster.
Norris, Richard S., London and North Western Railway, Engineer's Office, Liverpool.

Owen, William, Messrs. Sandford, Owen, and Watson, Phœnix Forge, Rotherham.

Paton, William, Edinburgh and Glasgow Railway, Locomotive Department, Cowlairs.
Payne, Edward J., 1, Bennett's Hill, Birmingham.
Peacock, Richard, Messrs. Beyer, Peacock, and Co., Gorton, near Manchester.
Pearson, John, Liver Iron Works, Boundary Street, Liverpool.
Penn, John, Messrs. John Penn and Co., Marine Engineers, Greenwich.
Pilkington, Richard, Jun., St. Helen's Foundry, St. Helen's.
Plant, Reuben, Pensnett Collieries, Brierley Hill, near Dudley.
Porter, John Henderson, Iron Roofing Works, Gas Street, Birmingham.
Preston, Robert B., 10, Abercromby Square, Liverpool.
Prideaux, Thomas Symes, 32, Charing Cross, London.

Ramsbottom, John, London and North Western Railway, Locomotive Department, Longsight, Manchester.
Richards, Thomas, 30, Hill Morton Road, Rugby.
Robertson, Henry, Shrewsbury and Chester Railway, Shrewsbury.
Robinson, Henry, 8, Chandos Street, Cavendish Square, London.
Roche, David M., East Indian Railway, Howrah, Calcutta.
Rofe, Henry, Birmingham Water Works, Paradise Street, Birmingham.
Rogers, Ebenezer, Abercarne, near Newport, Monmouthshire.
Rogers, Jonathan, Pontypool Iron Works, near Newport, Monmouthshire.
Rolinson, Thomas, Wellington Road, Dudley.
Ronayne, Joseph P., (per T. Mahony,) 3, Camden Quay, Cork.
Ross, John, Messrs. Brown, Marshall, and Co., Britannia Carriage Works, Birmingham.
Russell, John Scott, F.R.S., 37, Great George Street, Westminster.

Samuel, James, 26, Great George Street, Westminster.
Scott, Michael, 26, Great George Street, Westminster.
Selby, George, Smethwick Tube Works, near Birmingham.
Shanks, Andrew, 6, Robert Street, Adelphi, London.
Shipton, James Alfred, Oak Farm Foundry, near Dudley.
Siemens, Charles William, 7, John Street, Adelphi, London.
Sinclair, Robert, Caledonian Railway, Locomotive Department, Glasgow.
Slate, Archibald, High Street, Redcar.
Slaughter, Edward, Avonside Iron Works, Bristol.
Smith, George, Wellington Road, Dudley.
Smith, George B., Oak Farm Iron Works, Dudley.
Smith, Henry, Victoria Iron Works, Smethwick.
Spencer, Joseph, Bilston Foundry, Bilston.
Spencer, Thomas, Vulcan Iron Works, Westbromwich.
Spencer, Thomas, Newburn Steel Works, Newcastle-on-Tyne.
Stenson, William, Jun., Whitwick Collieries, near Ashby-de-la-Zouch.
Stewart, John, Blackwall Iron Works, Russell Street, Blackwall, London.

Thompson, Isaac, Messrs. Kitson and Co., Airedale Foundry, Leeds.
Thompson, James, Pin Mill, Ardwick, Manchester.
Thomson, George, Corngreaves, near Birmingham.
Thornton, Robert, 60, New Buildings, North Bridge, Edinburgh.
Thornton, Samuel, Bradford Street, Birmingham.
Tiernay, James B., Horseley Iron Works, near Tipton.
Turton, Thomas Burdett, Sheaf Works, Sheffield.

Walker, Thomas, Patent Shaft Works, Wednesbury.
Walker, Thomas, 50, Oxford Street, Birmingham.
Warham, John R., Iron Works, Burton-on-Trent.
Weallens, William, Messrs. R. Stephenson and Co., South Street, Newcastle-on-Tyne.
Whitworth, Joseph, Chorlton Street, Manchester.
Williams, Benjamin, Oak Farm Iron Works, near Dudley.
Williams, Richard, Patent Shaft Works, Wednesbury.
Williams, Walter, Jun., Albion Iron Works, Westbromwich.
Wilson, Joseph W., Neithrop, Banbury, Oxon.
Wingate, Thomas, Whiteinch Foundry, Partick, near Glasgow.
Woodhouse, Henry, London and North Western Railway, Stafford.
Woodhouse, John Thomas, Midland Road, Derby.
Wright, Henry, Saltley Works, Birmingham.
Wright, Joseph, Saltley Works, Birmingham.
Wymer, Francis W., 7, Hewgill Terrace, Newcastle-on-Tyne.

LIFE MEMBERS.

Maudslay, Henry, 4, Cheltenham Place, Lambeth, London.
Stephenson, Robert, M.P., 24, Great George Street, Westminster.

HONORARY MEMBERS.

Alston, William Charles, Leak Street, Birmingham.
Branson, George, Belmont Row, Birmingham.
Clare, Thomas Deykin, Midland Railway Station, Birmingham.
Crosby, Samuel, Leak Street, Birmingham.
Gwyther, Edwin, Belmont Row, Birmingham.
Heane, Henry, Newport, Shropshire.
Knight, George, 3, Craven Villas, Uxbridge Road, Ealing, Middlesex.
Peto, Sir Samuel Morton, Bart., 9, Great George Street, Westminster.
Sutton, William, Snow Hill, Birmingham.
Warden, William Marston, Edgbaston Street, Birmingham.

Wills, William Ridout, Waterloo Street, Birmingham.
Woolley, Rev. Joseph, LL.D., Royal Dockyard, Portsmouth.

HONORARY LIFE MEMBERS.

Hodgkinson, Eaton, F.R.S., 44, Drayton Grove, Brompton, London.
MacGregor, James, National Club, Whitehall Place, London.

GRADUATES.

Glydon, George, Spring Hill Works, Eyre Street, Birmingham.
Potts, J. Thorpe, Messrs. Fox, Henderson, and Co., London Works, Birmingham

PROCEEDINGS.

JANUARY 24, 1855.

The EIGHTH ANNUAL GENERAL MEETING of the Members was held at the house of the Institution, Newhall Street, Birmingham, on Wednesday, 24th January, 1855; WILLIAM FAIRBAIRN, Esq., President, in the Chair.

The Minutes of the last General Meeting were read by the Secretary and confirmed.

The Secretary then read the following

ANNUAL REPORT OF THE COUNCIL.

1855.

The Council have the pleasure, on the occasion of the Eighth Anniversary of the Institution, of reporting to the Members the satisfactory position and successful progress of the Institution.

The Financial statement of the affairs of the Institution for the year ending 31st December, 1854, shows a balance in the Treasurer's hands of £266 1s., after the payment of all accounts due to that date. The Finance Committee have examined and checked all the receipts and payments of the Institution for the last year, 1854, and report that the following Balance Sheet rendered by the Treasurer is correct.

(See Balance Sheet appended.)

The number of Members of all classes for the last year is 228, of whom 15 are Honorary Members, and 3 are Graduates.

The Council have to report the decease of the following Members of the Institution during the past year.

WILLIAM DENNY, . . of Dumbarton.
CHARLES GEACH, . . . London.
JOHN GRAY, ... Bradford.
JONATHAN HARLOW, . . Birmingham.
CHARLES RONTGEN, . . London.
WILLIAM SMITH, . . . Dudley.

The Council have the pleasure of acknowledging the following Donations to the Library of the Institution during the past year:—

Memoirs of the Literary and Philosophical Institution of Manchester, from the commencement in 1781, presented by W. Fairbairn, Esq.

Transactions of the Royal Scottish Society of Arts, from 1834, by the Council.

Transactions of the Liverpool Polytechnic Society.

Abstract of Proceedings of the Institution of Civil Engineers.

Journal of the Society of Arts.

On the Construction of Fish-Joints for Railways, by A. Malberg, from the Author.

Experiments upon the Strength of Rails by the Prussian Government in 1851, from M. Malberg.

Results of Trials of Locomotives by the Prussian Government in 1853, from M. Malberg.

On the Combustion of Coal and Prevention of Smoke, by C. Wye Williams, from the Author.

On the Iron-making Resources of the United Kingdom, by S. H. Blackwell, from the Author.

Artizan Journal, from the Editor.

Civil Engineer and Architect's Journal, from the Editor.

London Journal of Arts, from the Editor.

Mechanic's Magazine, from the Editor.

Special Report on the Machinery in the New York Industrial Exhibition, by Mr. Joseph Whitworth, from the Author.

Report of the British Commissioners in the New York Industrial Exhibition, from Mr. Joseph Whitworth.

Donation of £5 for purchase of Books, from Mr. W. Hawkes.

Portrait of J. F. Ledsam, Esq., presented by Mr. J. E. Clift

Original Working Model of New Water Meter, by Mr. C. W. Siemens, of London.

Specimen of New Water Meter, by Mr. John Taylor, of Manchester.

The Council have much satisfaction in referring to the valuable character of the papers that have been brought before the Institution during the past year, and expressing their thanks to the Authors of the papers for the practical information communicated by them. The Council wish to urge on the attention of the Members the importance of their aid in promoting the objects of the Institution, by contributing papers on engineering subjects that have come under their observation, and communicating the particulars of executed works, with the results of their practical working, that may be serviceable and interesting to the Members. The Council invite communications from the Members and their friends, upon the subjects in the list appended, and other subjects advantageous to the Institution; and also contributions to the Library, and to the collection of Mechanical Models and Drawings.

The following Papers have been read at the Meetings during the last year:—

On an Improved Water Meter; by Mr. C. W. Siemens, of London.

On an Improved Locomotive Engine; by Mr. Joseph Beattie, of London.

On Berdan's Crushing and Amalgamating Machine; by the Secretary.

On a New Railway Train Signal; by Mr. Edward J. Payne, of Birmingham.

On a Safety Apparatus for Working Mine Shafts; by Mr. Archibald Slate, of Dudley.

On an Improved Construction of Moulds for Casting Metals; by Mr. Robert Jobson, of Dudley.

On an Improved Piston for Steam Engines; by Mr. John Ramsbottom, of Manchester.

On an Improved Water Filter; by Mr. Archibald Slate, of Dudley.

Description of the Wrought-Iron Roof over the Central Railway Station at Birmingham; by Mr. Edward A. Cowper, of London.

On Kind's Improved System of Boring; by Mr. Samuel H. Blackwell, of Dudley.

Description of an Improved Steam Travelling Crane; by Mr. William Fairbairn, of Manchester.

On a New Steam Engine Boiler; by Mr. Thomas Forsyth, of Wolverton.

On Prideaux's Self-Closing Valve for Preventing Smoke in Steam Boiler and other Furnaces; by Mr. John E. Hodgkin, of Birmingham.

Description of an Improved Locomotive Piston; by Mr. James E. McConnell, of Wolverton.

On an Improved Steam Engine Boiler; by Henry Wright, of Saltley.

Description of a Friction Hammer; by Mr. James Kitson, of Leeds.

It is with feelings of deep regret that the Council have to refer to the decease of the respected Treasurer of the Institution, the late Mr. Charles Geach, who had filled that office from the commencement of the Institution; since his decease, Mr. Henry Edmunds, Manager of the Birmingham and Midland Bank, has kindly consented to carry on the duties of the office, *pro. tem.*, until the present Annual Meeting, when a Treasurer has to be elected.

The Officers of the Institution, and five of the Members of the Council in rotation, will go out of office this day, according to the Rules of the Institution; and the ballot will be taken at the present Annual Meeting for the election of the Officers and Council for the ensuing year.

The CHAIRMAN moved that the report now read be received and adopted.

The motion was seconded by Mr. Everitt, and passed.

Mr. Fothergill then moved that the following Rule of the Institution be expunged:—Section VII., Rule 1. "Every member shall lay one communication, at least, before the Institution, in each year, tending to advance professional knowledge; or shall pay a fine of £1 towards the library funds." He stated that the rule had never been acted upon, and suggested that it would be preferable to remove it from the Rules of the Institution.

The motion was seconded by Mr. Clift, and passed.

The Chairman announced that the Ballot Papers had been opened by the Committee appointed for the purpose, and the following Officers and Members of Council were duly elected for the ensuing year:—

PRESIDENT.

William Fairbairn, . . . Manchester.

Vice-Presidents.

Samuel H. Blackwell, . . Dudley.
James E. McConnell, . . Wolverton.
John Penn, ... London.
Archibald Slate, ... Dudley.
John Scott Russell, . . . London.
Joseph Whitworth, . . . Manchester.

COUNCIL.

John Henderson, ... Birmingham.
Matthew Kirtley, ... Derby.
James Kitson, ... Leeds.
Henry Maudslay, ... London.
John Ramsbottom, ... Manchester.
Henry Wright, ... Birmingham.

SECRETARY.

William P. Marshall, . . Birmingham.

The following New Members were also elected:—

MEMBERS.

JOHN HOWARD BLACKWELL, .	Smethwick.
WILLIAM BECKETT JOHNSON, .	Manchester.
CHARLES CLEMENT WALKER, .	Tipton.

Mr. SAMPSON LLOYD moved that Mr. Henry Edmunds, of the Birmingham and Midland Bank, be appointed the Treasurer of the Institution.

The motion was seconded by Mr. THORNTON, and passed.

The CHAIRMAN said he wished to express his thanks to the members for the honour he had received of being again elected President of the Institution. It was a great pleasure to him to assist by all means in his power in the advancement and benefit of the Institution, and his best exertions should be always devoted to carrying out that object; and he felt confident of its successful progress under the active and cordial support of the Officers and Council.

He felt a great interest in the Institution, and he considered it an honour to occupy his present position in an Institution so eminently useful and practical in character, which had made such important progress, and which had had two such distinguished men preceding him in his present office—their greatly respected first President, whose memory all revered, and whose genius and indomitable perseverance had realised for mankind the incalculable benefits of railway communication—and his son, their last President, who had done so much to advance the engineering works of the world.

To the mechanical engineers of this and other countries they were indebted for many advantages and comforts of which their forefathers were deprived; and the labours and discoveries of Watt and Arkwright and many others showed what had been effected in all the requirements of mechanical science, and the advantages and benefits that may be reasonably anticipated in the further development of an art which was far from being exhausted, and in so many directions offered a wide field for the exercise of the talents and energies of the active student. These considerations were important stimulants for exertion, well deserving the attention of all members of the Institution.

The Chairman congratulated the members on the very prosperous and cheering position of the Institution, and observed it was very gratifying to see so successful and continued a progress; and from its growing prosperity and usefulness, he looked forward with the most sanguine expectations to a considerable increase of members and an extended sphere of action in every department and object contemplated by the Institution.

In the collection of a Library, a nucleus had been formed, from which he trusted would spring a valuable and extensive library for refer ence and consultation; such an Institution should possess a good library, and he trusted all the Members, and those interested in the advancement of the Institution, would bear in mind that donations of books would be thankfully received by the Council. In addition to the library, he looked forward to the prospect of forming a collection of models and drawings of mechanical contrivances; and he hoped the younger members would take the opportunity of adding to the stock of the Institution by presenting models and mechanical drawings that they might be able to prepare. From such contributions there would be formed in time a museum and record of inventions that would prove highly useful to the members, and generally beneficial as a public record.

The Chairman observed that in the papers read before the Institution, there had been a great number of valuable and useful subjects brought forward; and an important advantage arose from the opportunity for discussion, and the extent of practical information elicited at the meetings. The character and interests of the Institution had been well supported by the papers read, and he was confident the facilities afforded for bringing forward the subjects of papers would elicit from the Members a continued series of valuable communications, calculated to increase the efficiency, and advance the prosperity of the Institution.

The following Paper, by Mr. Robert Morrison, of Newcastle-on-Tyne, was then read:—

DESCRIPTION OF AN IMPROVED STEAM HAMMER.

The object of the Author in the invention of this Hammer has been to prevent the great wear and tear and liability to derangement, which have been experienced in the ordinary steam hammers, and which form a serious drawback to the use of this powerful and valuable tool.

In the ordinary Nasmyth's hammer, the hammer-head is attached to the lower end of the steam piston-rod, (as in the Diagram, Fig. 1, Plate 1,) and is guided in falling by sliding between the side cheeks of the frame, which have a shallow projecting rib entering a groove in each side of the hammer-head.

The nature of the working requires in practice a considerable amount of play to be left between the guiding cheeks and the hammer sides, to allow sufficient freedom for the hammer-head in falling, and this causes a violent shake and jar at each blow of the hammer. The blow being rarely in the centre of its face, causes part of the force to be spent in a side blow of the hammer against one of the guiding cheeks, and the continued repetition of these side blows indents and wears away rapidly the rubbing-faces of the guides and hammer, increasing the side play and the extent of injurious action. A serious jar is also felt by the piston at the other end of the rod at each blow of the hammer, which causes so rapid a failing of the packing as to make the frequent necessity (sometimes weekly) of repacking the piston, a very serious inconvenience and expense. Also, this often breaks the piston-rod close to the piston, or at its juncture with the hammer-block, and frequently breaks the cylinder cover at the same time.

Trials have been made in consequence of more imperfect kinds of packing which were less subject to wear, and even of solid pistons without packing, but the waste of steam of high pressure consequent on such expedients makes it very important to remove the necessity for them if possible.

In another form of steam hammer, Condie's, (shown in the Diagram, Fig. 2), the arrangement of the cylinder and piston is reversed, with the view of diminishing the above injurious action.

The cylinder rises and falls with the hammer, which is attached to the lower end of it, and it is guided by rubbing against the side

cheeks of the frame at top and bottom; the piston and piston-rod are fixed to the top of the frame, and the steam is admitted through the piston-rod, which is tubular, and lifts the cylinder by pressing against the top cover. In this arrangement of hammer the jar of the blow is not communicated to the piston, as in the other case, but the rubbing surfaces of the hammer-guides are exposed to a similar injurious action. The hammer is also liable to break the cylinder.

In the Improved Hammer, the subject of the present paper, (shown in Fig. 3,) the cylinder remains fixed, and the piston-rod itself is made to form the hammer, being enlarged in diameter and prolonged through the top of the steam cylinder, where the upper end is steadied by sliding between guides. By this arrangement the hammer is guided by two large stuffing-boxes at the top and bottom of the cylinder, and it works with great steadiness and freedom from friction, as the rubbing surface is a turned cylindrical piston-rod fitting closely in the stuffing-boxes, instead of the ordinary hammer-block sliding loosely between the cheeks of the frame.

This Hammer is shown in Figs. 4 and 5, Plates 2 and 3, which represent a 40 cwt. hammer on this construction, having a clear fall of 3 ft. 6 in., which the Author has had at work for the last five months, at the Ouseburn Engine Works, Newcastle-on-Tyne, working day and night, double shift. During this time there has not been half an hour lost by any derangement of the hammer; the packing is as tight and good as when put on, so that the cover has not been taken off the cylinder since the hammer started. The large stuffing-box is also packed with hemp, and has not been unpacked for the last nine weeks, and no enlargement is perceptible in the gland.

The hammer has been tried with 35, 40, and 50 lbs. pressure of steam, but has been found to work best at 40 lbs. per square inch; it is found after the first heat that no condensation takes place in the cylinder, in consequence of the bar getting hot, and any water that may accumulate when not working, is collected in the bottom flange of the large gland, and carried away by a tube.

Fig. 4 shows a back elevation of the hammer, and Fig. 5 a vertical section from front to back.

The main frame consists of two vertical standards AA, spread out at the foot and bolted down upon the foundation plate, through which the anvil-block B, is fixed; these frame standards have deep ribs carried backwards (as shown in the sectional plans, Figs. 6, 7, 8), and they are firmly bound together at the top by the transverse stay C, cottered into eyes in the standards.

The steam cylinder DD, 19 inches diameter, is cast with flanges EE, on each side, shown in Fig. 8, extending the whole length, and bolted in front of the standards, filling the lower part of the space between them, flush with the underside of the arch, and fitting in tight between lugs, so as to form a strong and solid bond between the two standards. The flanges EE, of the cylinder are flush with the back, so that the whole body of the cylinder projects forward in front of the frame. The top cover F, of the cylinder, and its stuffing-box, shown in plan in Fig. 7, are made in two halves; the deep bottom stuffing-box is solid, and cast with the cylinder, forming the end cover.

The hammer-bar and piston-rod GG, is of wrought-iron, 10 inches diameter, with the piston H, forged solid upon it in the middle of its length, a groove being turned upon the circumference of the piston to receive a single brass packing-ring, ¼ inch thick, packed behind with hemp. The upper cross-head I, is also forged in one piece with the bar, and its two sides are planed down to act as steadying guides, as shown in the plan, Fig. 6, by sliding in the two parallel vertical slots in the upper part of the frame, which are formed by two pairs of bars KK, bolted upon the faces of the main standards. The piston-rod is thus guided very perfectly and steadily throughout its stroke.

In putting the piston-rod into its place, its lower end is passed down into the cylinder from above, and through the bottom stuffing-box until the piston enters the cylinder. The upper divided cover F, is then put on the cylinder above the piston, and the two halves are bolted together, and then bolted down upon the cylinder in the usual manner, and the upper and lower stuffing-boxes are packed and screwed up steam-tight. The hammer-face L, is then cottered on to the lower end of the piston-rod, projecting beyond the bottom stuffing-box.

The valve gearing consists, as usual, of self-acting arrangements for

opening and shutting the steam-valve at the bottom and top of the stroke respectively, with means for varying the length of stroke of the hammer as may be required.

The slide valve M, is placed behind the steam cylinder, with a single port into the lower end of the cylinder, communicating with the steam-pipe N, and the eduction-pipe O; and the valve is worked from above by the lever Q, which is acted upon by a spring below, arranged to open the valve on the lever being released. The valve lever Q, is jointed to a vertical rod working in eyes attached to the framing, and consisting of two parts, R, S. The upper part R, is formed with a screw-thread, and is entered into an internal screw in the lower portion S, which is tubular, means being thus provided for elongating or shortening the rod according to the stroke. The valve is worked through the rod R S, by means of the arm T, which is struck by the ascending slide I, of the hammer-bar. The arm T, is fixed on a short horizontal spindle, carrying a short lever, the point of which is attached by two links to the rod R, so that when the arm is pushed outwards by the ascending hammer-bar, it causes the rod R S to descend and close the steam-valve. The length of the hammer's stroke depends upon the position of the arm T, and for the purpose of varying this, the spindle is carried in a bush, which slides in a vertical rod U, the lower end of which is screwed, and is passed through a nut in the centre of a small worm-wheel, retained in a fixed collar bearing, and actuated by a worm on the spindle V, which last is provided with a hand-wheel. The same spindle V has formed upon it another worm gearing into a small worm-wheel, which is formed with a central eye, for the passage through it of the tubular rod S. The worm-wheel turns this rod, so as to screw the top rod R in or out, by means of a groove and feather, thus not impeding its vertical movements. By turning the hand-wheel, the spindle and arm are raised or lowered, and at the same time the rod R S is elongated or shortened in an equal degree, so as always to maintain the same position relative to the arm T, and in order that this may have the same action upon the valve-lever in whatever position it may be vertically.

When the steam-valve is shut in the manner described, it is kept so until the descent of the hammer-bar by means of a catch Z, acting on a collar formed on the tubular piece S. This catch is thrown out by the

percussion of the hammer's blow, at whatever point the blow may take effect, according to the thickness of the work upon the anvil. The means by which this is effected, consists of a bar W, jointed to upper and lower crank levers, vibrating on pins projecting from the framing. The other ends of these levers are jointed to a vertical rod X, passing down to a short lever fixed on the spindle, which carries the catch Z, before referred to. The cross-head I, of the hammer-bar carries a small weighted kicker Y, which strikes against the bar W, on the descent of the hammer-bar, being caused to do so by the momentum of the fall and shock of the blow. This action depresses the rod X, and putting the catch Z off the collar of the rod S, allows the spring to raise the latter, and at the same time open the steam-valve so as to lift up the hammer for a fresh stroke.

The valve-lever Q, has a handle formed upon it, in order that it may be worked by hand.

With the working piston, piston-rod and hammer, in one solid piece, the liability to fracture and derangement of the details is very much diminished, whilst the hammering blows are of superior solidity and effect; and the bolting of the steam cylinder between the frame standards, at the junction of the arch, immediately above the anvil or working level, provides a most powerful stay for tying the frames well together, and preventing all lateral springing. Hence the hammer-face is most accurately directed down upon its work, and shoulders, collars, and other projections can be hammered down with certainty to their intended size and form, by means of the side of the hammer. The height of the arch in this hammer is of importance, as it allows any article that can be forged under it, to be turned round without removing it from off the anvil; whereas the guides in the other hammers have to be carried so near the anvil, that in forging a crank-axle, or any other large substance, it has to be drawn back from off the anvil by the crane to turn it round; and as this has to be often done, a great deal of time and heat is lost.

The position of the steam cylinder in front of the standards is also of great importance in this arrangement, as when the hammer is actually between the frame-pieces, the mass of material under the

hammer must be angled before it can be swaged, and if it cannot be angled, the operating workman must necessarily stand between the frame-pieces; but in the present place, the hammer is quite clear of the framing, so that the forgeman can swage, shape, or cut any work he may have under the hammer, without the necessity of standing at all beneath the framing arch.

The CHAIRMAN thought the hammer was well worth consideration; it appeared an improvement of importance in overcoming the practical difficulties that had been experienced in the use of the steam hammer, arising from breakage and wear; the jarring and concussion had been found very objectionable, and though the strength of the piston-rod was increased with a view to meet the difficulty, it was still found to break. Mr. Morrison's arrangement went still further, making the piston-rod so strong and heavy as to serve for the hammer itself, and it had an advantage in greater steadiness of action.

Mr. MORRISON remarked, that a very important practical advantage resulted from the steadiness and smoothness of the motion, in freedom from accidents and delays for repair and packing, instead of the frequent and often weekly stoppages ordinarily occurring from these causes. The hammer in use at his Works had been in constant work night and day during the five months since it was started (with the exception only of a week at Christmas). The original packing of the piston had remained in the whole time, and still continued steam-tight; it consisted of a single brass ring, about $\frac{1}{4}$ inch thick, with $\frac{1}{8}$ inch thickness of hemp packing behind. The only breakage that had yet occurred took place in the original hammer-head, which broke on the first or second day of working, from a defect in the casting; a new head was then put on, a very strong sound casting of Stirling's toughened iron, and this had remained on ever since; if it had failed it was intended to have tried a wrought-iron head, but that was not found requisite; nor had any other accident or repair occurred to the hammer.

In the first make of the hammer the cylinder was placed central between the frame standards (as shown in Fig. 9, Plate 3), which allowed

of a rather simpler construction, as it was not then requisite to have separate guides fixed on in front for the top head; but this make was subsequently abandoned, and the cylinder was fixed projecting in front of the frame, on account of the greater convenience afforded for the men in working.

The CHAIRMAN asked how the hammer-head was fixed on.

Mr. MORRISON explained that the head was bored out with a slight taper, and the rod keyed in like an ordinary piston-rod; all the working parts being fitted well and solid. From the mode of construction of the hammer a great advantage was obtained in solidity of the blow and durability in wear. The friction of the large piston-rod in the two stuffing-boxes, it was feared at first, might be found too great, and might interfere with the efficiency of the blow of the hammer, by retarding its fall; but no objection of this kind was experienced in practice; the blows were as quick and effective as those of the ordinary steam hammer, and the greater steadiness and accuracy was found very serviceable in forging down collars and such kinds of work.

Mr. CHELLINGWORTH inquired whether a condenser had ever been applied to the cylinder of a steam hammer, so as to have a vacuum above the piston in lifting, requiring less steam power.

Mr. T. FORSYTH said, that a vacuum hammer had been invented by Mr. Naylor, of Norwich, which had, he believed, been tried there at the Eastern Counties Railway Works, but he was not acquainted with the particulars of the trial, nor of the hammer.

Mr. FENTON had seen Mr. Morrison's hammer at work, and was well satisfied with it; it worked very well, and he thought it a decided improvement. He had found that the Nasmyth's hammers, besides great wear of the guides and pistons, were liable to break off the cheek guides by the side shock of the hammer. He had experienced several cases where new frames had to be cast, on account of the guide-bars being broken off. In Condie's hammer separate guides were fitted on, which could be replaced when broken, independently of the frame; but in Morrison's hammer, the guides for the hammer-head were dispensed with, and the injurious side shock was prevented.

Mr. MAY had found great difficulty at first in working a Nasmyth's hammer, which he had used at Ipswich, from the frequent breakages,

more particularly of the piston-rod; but this was afterwards entirely removed by mounting the anvil upon india-rubber springs. The anvil-block, weighing about 9 tons, was bedded upon 20 or 30 pieces of india-rubber (ordinary buffer rings, placed two together, one upon the other), the elasticity of which allowed the anvil to sink slightly under the blow, probably less than ¼ inch, and prevented the injurious concussion of the hammer, but did not perceptibly interfere with the efficiency of the blow upon the work.

Mr. Henderson had had two Nasmyth's hammers at work for a considerable time, and had not experienced so much difficulty in their working as had been mentioned; but the inconvenience of the frequent stoppages caused by repacking the piston or repairing breakages was certainly so serious, that he thought if the new hammer of Mr. Morrison continued as free from these defects as had been represented, it would have an important practical superiority.

He had found that the difficulties in repairs were greater in the first instance, because the first hammer fixed at London Works had the anvil fixed on concrete. The damage and repairs were lessened by making an alteration, and refixing the anvil-block on a deep foundation of timber (say to the extent of a cube of nine feet on each side), which provided sufficient elasticity, and prevented the shock from being so severe upon the hammer and machinery, without in any way interfering with the efficiency of working. A timber foundation of similar construction was applied afterwards, with the same advantage, to a second hammer.

These two hammers are employed entirely for forging Lieut. Rogers' small-palmed anchors, and in consequence of the nature of the work, which is chiefly bevelled forging, there is certainly additional side strain and additional risk of breakage. On account of the nature of the work, the necessity of moving it round and getting at all sides of it, in putting up the second hammer the ordinary standards which had been found objectionable were omitted. The cylinder and hammer are carried by two wrought-iron girders, spanning the full width of the shop, which is about 35 feet in the clear. These girders are fixed about 7 feet clear height from the shop floor, and the cylinder and guides are fixed in the centre of the length, so that the ordinary standards are dispensed

with, and the space is left uninterrupted and free all round the hammer, an arrangement which affords great facility for this particular kind of work.

Mr. Henry Maudslay observed, that Messrs. Maudslay, Sons, and Field had employed three Nasmyth's hammers for several years, and the principal difficulty they had experienced in working them was the breakage of the pistons, which had caused much trouble; but they had since applied solid wrought-iron pistons, and the hammers now worked very satisfactorily; he thought that if the piston and rod were forged in one, as suggested, the alteration would be found a great improvement.

A simple and useful apparatus had been attached to these hammers by their foreman, Mr. John Ballard (formerly of H. M. Dockyard, Woolwich), for the purpose of facilitating the changing of the mould or anvil-face, which deserved notice as very convenient, and a saving of time and labour. A hook was passed round the piston-rod and attached by a chain to the anvil-face, which was lifted out by making the hammer raise itself slowly by the steam, and any mould could be changed in the anvil-block in the same way by working the hammer; to change the mould, when lifted from the anvil, it was hooked on to a long chain suspended from a pulley in the roof, and by the pendulous motion of the chain after disengaging it from the hammer, the mould was swung away to a distant part of the shop, out of the way of the men, and another one was brought in its place; by this plan all the space round the hammer was kept clear for the work, and the moulds could be quickly changed when required.

Mr. Cowper remarked, that in the arrangement of Morrison's hammer, a considerable advantage was due to the circumstance that the weight of the hammer was distributed over the great length of the piston-rod, instead of being concentrated in a short block at the lowest point, as in Nasmyth's hammer. In the latter, the height of the hammer-block being only about double its breadth, a line drawn from its centre of gravity to one of the bottom edges would have a very considerable inclination, and consequently, whenever a blow was struck on the edge of the hammer face, a considerable proportion of the force of the blow would be received on the side guides as a severe lateral blow, the continued repetition of which would lead to injurious wear of the

face of the guides. But in Morrison's hammer, the height of the hammer-block itself being 12 or 14 times its breadth, its centre of gravity would be about in the position of the piston, and the corresponding line drawn to the bottom edge would have very little inclination, and consequently, the amount of lateral strain would be almost im perceptible. This circumstance appeared to him to account for the mode of guiding the piston-rod being found sufficient for the hammer, and the stuffing-boxes would most probably have failed, had not the source of lateral strain that existed in the ordinary hammer been removed. It was like striking a blow with the end of a long ram, as compared with the blow of a short hammer-head, and the effect would certainly be advantageous in the durability and steadiness of the hammer.

Mr. Beyer had not found any serious difficulty in the working of Nasmyth's hammer, during five years' experience of the working of one of them; it had worked very satisfactorily, and without any material repair for at least half the time. He had also had one in use for about four months at his own works, and had not experienced any trouble with it. He thought that Nasmyth's hammer, if kept up well in repair, and not allowed to continue working out of repair, proved a very efficient and satisfactory tool; and he did not see that a sufficient advantage was gained in the new form of hammer that had been described, to compensate for the additional guide and stuffing-box.

Mr. Fothergill inquired what kind of work had been forged with the Nasmyth hammer that had been last mentioned; as the amount of wear and injury would depend very much on the nature of the work, and whether light or heavy blows were required.

Mr. Beyer replied that the hammer had been employed for forging all kinds of uses for locomotive engine work, and would include all general varieties of work, both heavy and light.

The Chairman thought the form of steam-hammer brought forward by Mr. Morrison appeared a very ingenious arrangement, possessing advantages in the steadiness of its action and the accuracy with which the hammer was guided; the freedom from accident and repairs was also very satisfactory. If the hammer continued to work with so little repairs and trouble as had been stated, he thought it would certainly be an important improvement, and remove a source of serious inconvenience and expense in the ordinary steam hammer.

He proposed a vote of thanks to Mr. Morrison, which was passed.

The following paper, by Mr. Edward J. Payne, of Birmingham, was then read:—

ON A NEW MANUFACTURE OF COMPOUND METALLIC RODS AND BARS.

At a time like the present, when the high price of Iron is of such importance to the consumers of Rods and Bars, descriptions of iron very extensively employed in many of the staple trades of this neighbourhood, there may be some interest attached to the results of some experiments lately made with the view of producing an economical substitute for solid iron rods and bars, such as are mainly employed in the manufacture of fences, railing, hurdles, metallic bedsteads, and many other purposes.

The specimens now exhibited, though somewhat crude, serve to elucidate the principle of the process.

They are small samples cut from lengths of rods and bars rolled in the following manner:—Two skelps of iron of the requisite weight, previously ascertained, and of the section shown at A, in Fig. 2, Plate 4, are placed together to form a cylinder, as in Fig. 1: and two similar skelps, B B, but of a somewhat larger size, are laid round this cylinder in such a manner as to break or cross the joints, as shown in Fig. 1. The whole is then bound together with iron hoops or strong wire, and a short piece of solid metal driven into one end of this cylinder, which is then filled with sand, earth, or ashes, and well and tightly rammed and dried, after which the open end is plugged in the same way as the opposite one had been.

The billet thus charged is put in the furnace, and when at a sufficient heat is removed to the rolls, and rolled out precisely as solid iron; the sand core being reduced in very nearly the same proportion as the iron. The exactness of this proportion depends entirely upon the thorough ramming of the core in the billet, for if the sand be loose, it follows that by the compression of the core in

rolling, the iron makes up the deficiency in diameter, and a shorter length of rod than the billet was calculated to make is the result. Some of the specimens show this result clearly. The area of sand in the billet shown full size in section in Fig. 13, was one of iron to one of sand, or half sand, but after rolling and reducing it to the size of section in Fig. 14, and nearly 20 feet in length, it was found to have assumed the proportion of one and a half iron to one of sand, or only 2-5ths sand.

It will be perceived by the specimens, that the sand during the process has become by the heat and great pressure, a semi-vitreous body of exceeding hardness, so close in its texture as to bear a polish; and this appears to add (in conjunction with the tubular form of the metallic portion of the rod) very great additional strength;—for upon testing one of the specimens about 5-8ths of an inch in diameter against a length of solid iron rod of the same diameter, by placing both upon benches, and suspending weights from the centre, the compound rod was found to sustain without deflection a weight that nearly doubled up the solid rod.

Fig. 11 is a section shown half size of a billet 3 inches diameter, made of a single skelp turned up into a cylinder, and containing the same proportion of sand, viz., one half, after being rolled down to the size shown in Fig. 12, ¾ inch diameter, the result showed a diminution in the proportion of sand, the finished rod being in the proportion of 1½ iron to 1 of sand, or 2-5ths area of sand. This was done at the Cwm Avon Works in South Wales.

Some of the rods produced have been made from billets turned up into a cylinder from a flat skelp in gun-barrel rolls, and one from the breech end of a twisted gun-barrel; this was of course done merely as an experiment, as it appeared to be the worst description of tube for the purpose; the core however proved as sound as any of the rest. Generally speaking, the form of billet first described appears to be the best, and it is certainly the least expensive.

Thus far the manufacture has been described of round rods. For square rods and flat bars, the same description of billet is employed, varying only in section; thus, for a square rod, a billet

of the section shown in Fig. 5, composed of two skelps of a V form, as seen in Fig. 6, at FF, will be used; and for a flat bar, the section in Fig. 3, made of skelps of angle iron, as in Fig. 4, would be employed, the operation of rolling being identical with that now in use for solid iron.

It now remains to show the results attained by these experiments, as to the saving of cost in the manufactured rod. The most complete estimate in the possession of the writer is one furnished from the works in South Wales, where the greater portion of these experiments have been made, which is the following:—

Assuming the present price of the rolled skelps of the sections shown, to be

	£	s.	d.	
	9	10	0	per ton,
add	2	10	0	per ton, cost of making, ramming, and plugging the billets, including cost of sand.
add	1	0	0	per ton for contingencies and waste.
	£13	0	0	Total cost of working up one ton of iron into a length

equivalent to that which would be produced from two tons of solid iron; giving the price of the rods or bars containing half sand, £6 10s. per ton measurement, or a saving of about £3 for the same length of rod or bar. But it should be remembered that these experiments have been confined to the production of rods not exceeding one inch in diameter, and that as the diameter of the rod increases, a considerably greater proportion of sand than one half can be introduced, consequently a ton of iron may be made to produce more than two tons measurement of the larger rods or bars; this estimate of the saving on an average of all marketable sizes, would therefore be rather within the mark than otherwise.

The samples of rails upon the table, and shown in Figs. 8 and 10, were also rolled at the same works in South Wales, with a view of testing the applicability of the invention to effect a saving of metal in this branch of manufacture.

The piles shown in Figs. 7 and 9, were made in the usual manner, with upper and lower plates of No. 2 iron, the remainder

being puddled bars, and having a hollow in the centre, for the reception of the core; the sand was in this case first rammed in a core box, DD, made of plate iron, ¼ in. thick. In one of these piles the core was 4¼ inches, in the other, 3¼ inches square, but the ends were left unplugged; the result of the rolling showed that the sand assumed very much the form of the rail, but from the omission of the plugging, the area of the section of sand in the rails, as seen at SS, is not nearly so great in proportion as that of the one introduced in the pile.

Some samples of small copper tubes, made on the same principle as the iron rods, are also shown among the specimens, the only difference in their manufacture being, that the billets were in this case drawn cold, consequently, the sand, not being vitrified, was readily removed afterwards from the bar, leaving it an open tube; but these may be more easily made by charging the billets (the cylinders for which are cast as shown by the specimen exhibited) either with pure silica or plaster of Paris, neither of which will vitrify, and then rolling them hot in the same manner as the iron rods. This kind of core undergoing no change by the action of the fire, may be bored out with ease.

Further experiments are now being made, with the endeavour to produce rods having a mere skin of iron on the strong core, the result of which the writer will be happy to communicate on a future occasion.

The CHAIRMAN thought the subject of the paper appeared one of considerable interest, and well deserving consideration in connection with the present high price of iron. Some other applications of the plan might perhaps be worth considering, such as the case of long lines of shafting, where it would be useful to obtain great rigidity with a less quantity of iron. The value of the plan would depend much on a uniform regularity being obtained in the position of the sand core in the bars when finished; and he inquired the cause of some irregularity that appeared in the specimens of rails and some of the bars.

Mr. PAYNE replied that the specimens of rails were the results of only the first experiments, made for the purpose of trying the applicability of the process to such a manufacture, and the practicability of drawing down the sand and iron together under such circumstances. They were imperfect specimens of the process, and the irregularity in the sand core was caused by not having the sand rammed hard enough at the commencement, and not plugging up the ends of the billet. In forming a double-headed rail, it had been intended to introduce a sand core in the centre of each head, extending partly down the stalk of the rail, but separated by about an inch of solid iron in the centre of the stalk, for the purpose of tying the two sides of the metal together. The application of the process to rails had not, however, been considered of so much importance as its use in various forms of bar iron to which it appeared more particularly applicable.

The CHAIRMAN thought there would be considerable difficulty in the application of the process to rails, and there would be a danger of their bulging out in the centre. when subjected to the crushing action of the wheels rolling upon them.

Mr. MATHEWS asked whether the labour of ramming the sand into the pile, could be reduced by any process of running vitrified sand, or other liquid material, into the hollow centre of the pile?

Mr. PAYNE replied, that any process of that kind would require a complete tube to be first produced and filled with the material; but that by the present process, the expense of making a tube was avoided, and the skelps were welded together at the time of rolling out the whole; the object was to weld the tube by the same process as drawing down the compound bar

Mr. MAY remarked, that the core did not become vitrified in the process, but appeared to remain sand in all the specimens, and this constituted its value in the process; the heat was not sufficient to vitrify the sand, which remained solid, and did not melt or vitrify, but became only more condensed and drawn out in form.

Mr. FOTHERGILL observed, that the cores in many of the specimens were out of the centre, and in any application of the plan to the manufacture of shafting, it would be essential for the core to be

kept exactly in the centre; if there were any deviation in this respect it would be a serious objection, as the thickness of metal would be unequal, and might be almost cut through where journals were turned down upon the shaft.

Mr. Henry Maudslay suggested, that the shaft might be made solid at the ends if required to be turned down, and the other bearings made by shrinking on collars to avoid turning down the shaft, according to the present practice in ordinary solid shafting.

Mr. Fothergill thought there would be a difficulty in regulating the position of any solid parts in the manufacture of the shaft, to provide for turning down in the right place.

Mr. Fenton remarked, that if the core was not truly in the centre, the shaft would be out of balance and lob-sided, causing a very objectionable vibration and unsteadiness at high speeds.

Mr. Payne explained, that if the core was truly placed in the billet, it was found to remain quite true throughout the process of rolling. The early specimens shown were imperfect in this respect on account of the imperfection in forming the original billets in the first experiments; but by the present plan the two equal thicknesses of skelp forming the metallic portion of the rod, insured an equal thickness of metal all round, and a true position for the sand core; and in rolling down the bar the thickness of metal was found to be reduced with remarkable uniformity in all parts, so that he thought a correct central position of the core could be insured after some practice in the manufacture.

Mr. Clift inquired whether any experiments had been made to test the relative strength of the compound bars and tubes of the same size and thickness? he did not see that the sand core could add materially to the strength of the tube.

Mr. Payne replied, that a trial had been recently made of the transverse strength of one of the compound sand-bars $\frac{5}{8}$ inch diameter, compared with a tube of the same thickness of metal, and also a solid rod, all of the same external diameter; but in consequence of a slight inaccuracy in the sizes not being exactly the same, the experiment had not been stated; the result, however, was that the sand-bar was considerably stronger than the hollow tube, and it was also stiffer than the solid rod.

Mr. Everitt had witnessed the trials in making tubes by this process, but although the result was satisfactory in soundness of tube and uniform thickness of metal, he thought the expense of getting out a sand core would prove too great to allow of manufacturing tubes by this plan. For light bars, such as fencing, where stiffness was the main requisite, the method might be very advantageous, producing a rigid rod at less expense than bar-iron of the same stiffness.

Mr. Mathews asked what proportion of sand was proposed to be employed?

Mr. Payne replied, that $\frac{1}{2}$ sand had been hitherto used in the billet, which became reduced by the compression of rolling to about $\frac{2}{5}$ths sand with $\frac{3}{5}$ths iron in the finished rod; but it was expected that this proportion of iron would be reduced by further trials to $\frac{1}{2}$, or perhaps less in the finished rod.

The Chairman said, that on a future occasion they would be glad to receive the results of the further trial and application of the process; and he proposed a vote of thanks to Mr. Payne, which was passed.

The following paper, by Mr. James Fenton, of Leeds, was then read:—

DESCRIPTION OF AN IMPROVED SAFETY VALVE, FOR LOCOMOTIVE, MARINE, AND STATIONARY STEAM BOILERS.

The numerous steam-boiler explosions which have recently occurred in this country, have necessarily given this subject much interest and importance. Not only has a vast amount of property been destroyed, but many valuable lives have been lost through these fatal disasters—the average, it is believed, exceeding one per day.

There can be no doubt that in too many instances, the evil may be traced to the defective working, or total stoppage of the safety valves, either from overloading or otherwise; it has therefore become a matter

of importance to devise an arrangement of safety valve that is not liable to stick or lock itself; and for marine and stationary boilers more particularly, one that the engineer or boiler attendant cannot tamper with.

The Author believes that the Safety Valves described in the present paper, fulfil both these conditions, simply, cheaply, and effectively.

The single valve shown in Plate 5, is arranged for a locomotive boiler, and the double one, in Plate 6, for a locomotive, marine, or stationary boiler.

The improvement in these valves consists in the application of the ball and socket principle throughout the arrangement, and in the novel combination of the two valves under one lever.

The valve is a sphere resting upon a spherical seat, and is provided with cup and ball fittings to the lever and appendages. A cup rests immediately over the sphere, in connection with a lever, in which it is held by a spindle. One end of the lever is held upon a vertical spindle; the nut by which it is secured, is spherical at its lower end, and fits into a corresponding cup on the upper side of the lever. The long arm of the lever is provided with a like fitting, by which it is connected to the spindle of a spring balance, while the lower end of the spring balance spindle is connected by a similar one to a rod or arm projecting from the boiler; the object of these fittings is to allow of play at every joint, and in order further to prevent any part of this valve from sticking, care is taken that the parts which come in contact in forming the joints shall not be of the same metal. Fig. 1, Plate 5, is an elevation with the valve-seat in section of a locomotive safety valve; Fig. 2, a transverse section, and Fig. 3 a plan.

A is the valve, BB the valve-seat casing, which is cast in brass or gun metal, and bolted to the boiler by the flange. The valve-seat is formed out of a circular edge, turned and ground to fit accurately the valve A; the upper part of the valve-seat is dished out, in order that directly the valve is lifted from its seat by the pressure of the steam, there may be sufficient space for the steam to blow off freely. DD are four guides to insure the valve falling accurately into its seat; the valve A is cast hollow, and afterwards turned perfectly spherical, or as nearly so as possible; E is a cup or cap, cast concave, and ground to fit the

upper part of the valve; a projection or spindle is cast in a piece with the cup, and formed with a hemispherical end, which fits into a corresponding hemispherical cup, in the underside of the lever F; GG is a vertical spindle, the lower end of which is screwed into a snug cast upon the valve-seating; the upper part of this spindle is also cut with a screw thread, upon which is fitted the nut I, the underside of which is made spherical, and fits into a corresponding cup formed in the upper part of the lever F, a conical hole being drilled through the lever at this part, so as to enable it to be passed over the end of the vertical spindle, and retained there by the nut I, which thereby acts as a fulcrum to the lever. The opposite end of the lever is furnished with a similar nut and hole, through which the screwed end of the spindle K, of an ordinary spring balance I, is passed, the lower end of the box of the balance being fitted with a screwed spindle, which is passed through the rod or arm M, and fitted with a nut; the lever F is curved down at each end, in order to bring the centres of the spherical nuts in the same line with the central line of the lever, and thereby to render the action of the valve more accurate and certain.

Figures 4 and 5 show a double form of this safety valve, in which two of the valves are combined in such manner, that when any action takes place, either intentionally or otherwise, the tendency of which is to overweight the valve, one of the two immediately becomes a fulcrum about which the other is raised; N O are the two valves, each constructed in the same manner as the foregoing; P is a spiral spring, placed between the nut I and the end of the lever, which acts either as a fulcrum or as a weight to the lever, according to the adjustment of the spring balance, for should the spring balance be screwed down, or weighted to resist a greater pressure than the spiral spring, then the latter would become compressed and the steam blow off through the valve O; but should the spiral spring be screwed down to an excess of pressure over the spring balance, then the steam would blow off through the other valve N.

It may be remarked that the old class of valves may be readily and inexpensively altered to the single valve, on nearly all locomotive boilers, as the seatings, spring balances, and long ends of the levers,

can all be retained; and if required, the back spring may be applied by simply lengthening the fulcrum bolt.

Several of these valves have been in use on the locomotive engines on the York and North Midland Railway, for the last seven months, with the most complete success.

The double valve is virtually a "lock-up valve," being so arranged that the balls alternately become the fulcrums for each other, as the spring balance is screwed above, or below the point of adjustment; at that point alone do they both blow off.

Supposing the required working pressure in the boiler to be 100 lbs. per square inch, the back spring and spring balance are adjusted till both valves blow off simultaneously; the former is then locked up, placing both valves beyond the control of the party in charge of the boiler. The spring adjustment at each end of the lever must insure an additional amount of safety, as there is really no sticking point left in the whole arrangement, and should either spring get out of order, it can at once be ascertained which is defective, by moving the long end of the lever up and down.

Two spring balances coupled together are shown on the drawing, with the view of using the old ones, when the double valve is applied to the present locomotive boilers.

Several of these valves are now at work on stationary boilers, and perfectly fulfil all the conditions required.

The guide R, applied to the lever, may be dispensed with, by properly adjusting the taper of the holes in the lever and arm for holding the bottom of the spring balance.

The Chairman said, the proposed arrangement of valve appeared to have much ingenuity and merit; the double lock-up valve was particularly simple and complete, both the valves being locked in effect, but still free to move and blow off.

Mr. Fenton remarked, that it was found a practical advantage of much importance that the lock-up spring was adjusted to the required limit of pressure by the open spring balance alone; thus

entirely avoiding the uncertainty of pressure adjustment that existed in many lock-up springs, arising from difficulty in measuring the pressure accurately when adjusted, and from change in the elasticity of the spring during use. In the new arrangement this pressure was continually checked by the open spring balance, and could be readily tested with certainty, by screwing down the spring balance until the lever began to lift up the locked spring by acting upon the front valve as a fulcrum; the arrangement formed a simple and convenient mode of obtaining the advantage of a lock-up safety valve with the ordinary pair of open valves, without interfering with their action.

The CHAIRMAN asked whether any other form of spring, such as a flat volute spring, had been tried for the lock-up spring; he thought the ordinary spiral spring would probably not be found the best for the purpose, as it did not stand so well under very heavy pressure.

Mr. FENTON replied, that a trial of some volute springs was expected to be made shortly, but there had been found a difficulty at first in getting them made suitable for the purpose; the spiral spring that was shown had however been found to stand satisfactorily in the valves that were at work, and when a greater pressure was required than could be well obtained with a single spring, a second spiral spring was added in the interior of the first one, without occupying more space, or altering the outer casing.

Mr. FOTHERGILL had known the ordinary safety valves stick in many cases in the joints of the levers, arising from dirt, and also inaccuracy in the fitting, and consequent imperfection in the bearing of the several moving parts, causing oblique strain and friction; but the new valve of Mr. Fenton entirely avoided this cause, and the arrangement was certainly very perfect in insuring always a correct action of all the parts.

Mr. MAY inquired whether any particular process had been adopted for getting up the balls of the safety valves. Ball-valves could be made to fit very accurately; he remembered a remarkably perfect specimen that was made by an old foreman of Messrs. Donkin's,—it was a glass sphere dropping into a steel plate with a

thin knife-edge round the aperture, and it fitted perfectly air-tight, although the surface of contact was so exceedingly minute.

Mr. FENTON replied that the best plan he knew for the purpose was that used by Mr. Ramsbottom, for getting up the ordinary ball-valves of pumps; two cast-iron cups were employed, revolving in opposite directions, one inverted over the other, and the ball was ground between them with emery. The cost of getting up the pump-valves was, he believed, very small by this plan, only about 1½d. per ball, and they were made very perfect.

Mr. FOTHERGILL remembered seeing in an old list of patents, that a machine had actually been patented for the purpose of grinding children's marbles by a similar plan.

Mr. ADAMS remarked that the common mode of grinding children's marbles was a curious instance of simplicity in machinery; a number of stone chips, broken to size, were put together in a tin box and fastened to the rim of a water-mill wheel, and there left to grind themselves into shape.

The CHAIRMAN inquired what was the relative expense of the new safety valves, compared with that of the ordinary ones?

Mr. FENTON replied that the single valves were about the same cost as the ordinary ones, but the double valves combined under one lever, were about one-third less cost than a corresponding pair of ordinary valves; the cost was about £13 for the double valve, and £10 for the single one, including the spring balances.

The CHAIRMAN thought the plan was an ingenious improvement to prevent sticking of the valves, and the consequent risk of accident, by insuring a constant free action; and it was a very simple and efficient arrangement for obtaining a lock-up valve.

He proposed a vote of thanks to Mr. Fenton, which was passed.

The following Paper, by Mr. John Ross, of Birmingham, was then read:—

The end of the inner pipe is made a few inches longer than necessary, to allow of cutting off the nozzle, whenever burnt out, and shortening the tuyere by welding on another ring to form the nozzle.

The Author has had seven of these wrought-iron tuyeres in constant use, one for 11 months, and the rest for an average of six months, without any perceptible wear.

The CHAIRMAN inquired where the improved tuyeres were at work, and to what extent they had been adopted?

Mr. Ross replied, that there were many of them in use in Derby, and a number at his own works, and some other works in Birmingham; but he was not aware whether they had got into use elsewhere to any extent at present. He had expected Mr. Lee to be present at the meeting, who would have been able to give more information about their use. Mr. Lee had used the first of these tuyeres about eight years ago, but those at his own works had been only two or three years in use. These were all cast iron, but made so as to admit of adopting the proposed wrought-iron nozzles afterwards in the course of repair, as he considered wrought iron so much better for the purpose as to be worth the extra cost. All those that he had used had continued at work satisfactorily, without giving any trouble; except a few of the first which had the tuyere placed below the bottom of the cistern, attached to the underside, and were found to get choked up in time by the sediment depositing in the water space of the tuyere; all the others, which were attached at the side of the cistern above the bottom, remained entirely free from obstruction.

Mr. BEYER had seen a similar construction of tuyere before, and considered it a good plan, and he had adopted it at his own works recently, as preferable to the ordinary water tuyeres; he thought it was as much as twelve years since it was first introduced.

Mr. JONES remembered also a similar tuyere in use earlier than that time.

The CHAIRMAN remarked that the mechanical value of the

invention was the more important question for consideration, rather than that of priority of invention.

Mr. Fernie said that as successor to Mr. Lee, at the Britannia Foundry, Derby, he could speak to the wear and efficiency of the improved tuyeres, and he had found them very durable and satisfactory in work. He had a considerable number in constant use, and none of them had required replacing during the last two years; they continued quite sound and in good order, although all of them were cast of the simplest form, as in the first drawing shown, Fig. 3. He had not found any disadvantage from making them of cast iron, and it was an important point in such things to obtain cheapness and simplicity of construction; any adoption of wrought iron for the purpose, would add materially to the cost, and he did not think, from his own experience, that it was required.

The Chairman thought the tuyere appeared a decidedly useful improvement, and it was one of those cases of simple inventions, that were often very useful and serviceable to be brought before the members. He proposed a vote of thanks to Mr. Ross, which was passed.

The meeting then terminated, and after the meeting, Mr. Andrew Shanks, of London, exhibited a specimen of his improved Pressure Gauge.

In the evening a number of the Members and their friends, including several guests invited on the occasion, dined together in celebration of the Eighth Anniversary of the Institution.

INSTITUTION OF MECHANICAL ENGINEERS.

BALANCE SHEET.

For the year ending 31*st December*, 1854.

Dr.	£	s.	d.
To Balance 31st December, 1853	194	12	9
,, Subscriptions from 13 Members in arrear	39	0	0
,, ditto 1 Graduate ditto	2	0	0
,, ditto 165 Members for 1854	495	0	0
,, ditto 2 Graduates ditto	4	0	0
,, ditto 24 new Members	120	0	0
,, ditto 5 Members in advance for 1855	15	0	0
,, Donation to Library	5	0	0
,, Sale of Extra Reports	20	19	0
,, Interest from Bank	1	9	0
	£897	0	9

Cr.	£	s.	d.
By Printing and Engraving, Reports of Proceedings	99	17	6
,, Stationery and Printing	12	8	4
,, Office Expenses and Petty Disbursements	22	15	11
,, Furniture and Fittings	6	13	11
,, Travelling Expenses	3	10	0
,, Parcels	4	16	8
,, Postages	17	1	11
,, Salary	350	0	0
,, Rent and Taxes	113	15	6
,, Balance 31st December, 1854	266	1	0
	£897	0	9

(Signed) J. E. CLIFT, S. H. BLACKWELL, Finance Committee.

22*nd January*, 1855.

SUBJECTS FOR PAPERS.

STEAM ENGINE BOILERS, particulars of construction—form of heating surface—relative value of radiant surface in effect and economy—cost—consumption of fuel—evaporation of water—pressure of steam—steam gauges, high pressure and low pressure—explosion of boilers, and means of prevention—effects of heat on the metal of boilers, low pressure and high pressure—incrustation of boilers, and means of prevention—evaporative power and economy of different kinds of fuel, coal, wood, charcoal, peat, patent coal, and coke—moveable grates, and smoke-consuming apparatus, facts to show the best plan, and results of working.

STEAM ENGINES, expansive force of steam, and best means of using it—power obtained by various plans—comparison of double and single cylinder engines—comparative advantages of direct-acting and beam engines—indicator figures from engines, with details of useful effects, consumption of fuel, &c.—contributions of indicator figures for reference in the Institution.

PUMPING ENGINES, particulars of various constructions—size of cylinder and pumps—strokes per minute, and horse-power—number and size of pumps, and strokes per minute—comparison of double-acting and single-acting pumping engines—particular details of different valves—application of pumps—fen-draining engines—comparative advantages of scoop wheels and centrifugal pumps, lifting trough, &c.

BLAST ENGINES, best kind of engine—size of cylinder, strokes per minute, and horse-power—details of boilers—size of blowing cylinder, and strokes per minute—pressure, and means of regulating the blast—improvements in blast cylinders—rotary blowing machines.

MARINE ENGINES, power of engines in proportion to tonnage—different constructions of engines—dynamical effect compared with indicator figures—comparative economy and durability of different boilers, tubular boilers, flat flue boilers, &c.—weight of machinery and boilers—kind of paddle wheels—speed obtained in British war steamers, in British merchant steamers, and in Foreign ditto, with particulars of the construction of engines with paddle wheels, &c.—screw propellers, particulars of different kinds, improvements in the form, number of arms, material, means for unshipping, horse-power applied, speed obtained, section of vessel—iron and wood ships, details of construction, lines, tonnage, cost, &c.

ROTARY ENGINES, particulars of construction and practical application—details of the results of working.

LOCOMOTIVE ENGINES, express, passenger, and luggage engines—particulars of construction, details of experiments, and results of working—speed of engines, cost, power, weight, steadiness—consumption of fuel—heating surface, length and diameter of tubes—experiments on size of tubes and blast pipe—comparative expense of working and repairing—best make of pistons, valve gear, expansion gear, &c.

SUBJECTS FOR PAPERS.

Caloric Engines, and Engines worked by Gas, Gun-cotton, or other explosive compounds—comparative consumption per horse-power per hour.

Electro-Magnetic Engines, particulars and results.

Water-Wheels, particulars of construction and dimensions—form and depth of buckets—head of water, velocity, per-centage of power obtained—turbines, construction and practical application, power obtained, comparative effect and economy.

Wind Mills, particulars of construction—number of sails, surface and form of sails—velocity, and power obtained—average number of days' work per annum.

Corn Mills, particulars of improvements—power employed—application of steam power—results of working with an air blast and small stones—advantages of regularity of motion.

Sugar Mills, particulars of construction and working—results of the application of the hydraulic press in place of rolls.

Saw Mills, particulars of construction—mode of driving—power employed—particulars of work done—best speeds for vertical and circular saws—form of saw teeth—saw mills for cutting ship timbers—veneer saws.

Oil Mills, facts relating to the construction and working, by stampers and by pressure.

Cotton Mills, information respecting the construction and arrangement of the machinery—power employed, and application of power—cotton presses, mode of construction and working, power employed—improvements in spinning and carding machinery, &c.

Machinery for manufacturing Flax, both in the natural length of staple and when cut.

Rolling Mills, improvements in machinery for making iron and steel—mode of applying power—steam hammers—piling of iron—plates—fancy sections.

Stamping and Coining Machinery, particulars of improvements, &c.

Paper-Making and Paper-Cutting Machines, ditto ditto

Printing Machines, ditto ditto

Calico-Printing Machinery, ditto ditto

Water Pumps, facts relating to the best construction, means of working, and application—best forms—velocity of piston—construction of valves.

Air Pumps, ditto ditto ditto

Hydraulic Presses, facts relating to the best construction, means of working, and application.

Rotary and Centrifugal Pumps, ditto ditto ditto

Fire Engines, ditto ditto ditto

Sluices and Sluice Cocks, ditto ditto ditto

Cranes, ditto ditto ditto

Steam Cranes, Hydraulic Cranes, Pneumatic Cranes, ditto

Lifts for raising Trucks, &c. ditto ditto ditto

LATHES, PLANING, BORING, AND SLOTTING MACHINES, &c., particulars of improvements—description of new self-acting tools.

TOOTHED WHEELS, best construction and form of teeth—results of working—power transmitted.

DRIVING BELTS AND STRAPS, best make and material, leather, rope, wire, gutta percha, &c.—comparative durability, and results of working—power communicated by certain sizes.

DYNAMOMETERS, pressure-gauges, governors, construction and working.

STRENGTH OF MATERIALS—facts relating to experiments on ditto, and general details of the proof of girders, &c.—girders of cast and wrought-iron, particulars of different constructions, and experiments on them—best forms and proportions of girders for different purposes—best mixture of metal—mixtures of wrought iron with cast.

DURABILITY OF TIMBER of various kinds—best plans for seasoning timber and cordage—results of Kyan's, Payne's, Bethell's, and Burnett's processes, &c.—comparative durability of timber in different situations.

CORROSION OF METALS by salt and fresh water, and by the atmosphere, &c.—facts relating to corrosion, and best means of prevention—means of keeping ships' bottoms clean.

ALLOYS OF METALS—facts relating to different alloys.

FRICTION OF VARIOUS BODIES—facts relating to friction under ordinary circumstances—friction of iron, brass, copper, tin, wood, &c.—proportion of weight to rubbing surface—best forms of journals, and construction of axle-boxes, &c.—lubrication, best materials and means of application, and results of practical trials—best plans for oil tests.

IRON ROOFS, particulars of construction for different purposes—durability in various climates and situations—comparative cost, weight, and durability—roofs for slips of cast-iron, wrought-iron, timber, &c., best construction, form, and material—details of large roofs, and cost.

FIRE-PROOF BUILDINGS, particulars of construction—most efficient plan—results of trials.

CHIMNEY STACKS of large size, particulars, mode of building, cheapest construction, &c.

BRICKS, manufacture and durability—hollow bricks, fire-bricks, and fire-clay—perforated bricks, cost of manufacture, and advantages.

GAS WORKS—best form, size, and material for retorts—construction of retort ovens—quantity and quality of gas from different coals—oil gas, water gas, &c.—improvements in purifiers, condensers, and gas-holders—wet and dry gas-meters—pressure of gas, gas-exhauster—gas-pipes, strength and durability, and construction of joints—proportionate diameter and length of gas-mains, and velocity of the passage of gas—experiments on ditto, and on the friction of gas in mains, and loss of pressure.

WATER WORKS—facts relating to water works—application of power, and economy of working—proportionate diameter and length of pipes—experiments on the discharge of water from pipes, and friction through pipes—strength and durability of pipes, and construction of joints—relative advantages of stand-pipes and air-vessels.

WELL SINKING, AND ARTESIAN WELLS, facts relating to.

COFFER DAMS AND PILING, facts relating to the construction.

PIERS, fixed and floating, and Pontoons, ditto ditto.

PILE-DRIVING APPARATUS, particulars of improvements—use of steam power—Pott's apparatus—the compressed air system.

DREDGING MACHINES, particulars of improvements—application of dredging machines—power required, and work done.

DIVING BELLS AND DIVING DRESSES, facts relating to the best construction.

CAST-IRON AND WROUGHT-IRON LIGHTHOUSES, ditto ditto

MINING OPERATIONS, facts relating to mining—means of ventilating mines, use of steam jet and ventilating machinery—mode of raising materials—mode of breaking, pulverising, and sifting various descriptions of ores.

BLASTING, facts relating to blasting under water, and blasting generally—use of gun-cotton, &c.—effects produced by large and small charges of powder.

BLAST FURNACES—consumption of fuel in different kinds—burden, make, and quality of metal—pressure of blast—horse-power required—economy of working—improvements in manufacture of iron—comparative results of hot and cold blast.

PUDDLING FURNACES, best forms and construction—worked with coal, charcoal, &c.

HEATING FURNACES, best construction—consumption of fuel, &c.

SMITHS' FORGES, best construction—size and material—power of blast—hot blast, &c.

SMITHS' FANS, and FANS generally, best construction, form of blades, &c., with facts relating to the amount of power employed and the per-centage of effect produced.

COKE AND CHARCOAL, particulars of the best mode of making, and construction of ovens, &c.

RAILWAYS—construction of permanent way—section of rails, and mode of manufacture—experiments on rails, deflection, deterioration, and comparative durability—material and form of sleepers, size, and distances—improvements in chairs, keys, and joint fastenings—permanent way for hot climates.

SWITCHES and CROSSINGS, particulars of improvements, and results of working—advantages obtained by steeling points and tongues.

TURN-TABLES, particulars of various constructions and improvements.

SIGNALS for Stations and Trains, and self-acting signals.

BREAKS for Carriages and Waggons, best construction.

BUFFERS for Carriages, &c., and Station Buffers—different construction and materials.

SPRINGS for Carriages, &c., buffing and bearing springs—particulars of different constructions and materials, and results of working.

RAILWAY WHEELS, wrought-iron, cast-iron, and wood—particulars of different constructions, and results of working—comparative expense and durability—wrought-iron and steel tires, comparative economy and results of working—solid wrought-iron wheels.

RAILWAY AXLES, best description, form, material, and mode of manufacture—comparison of solid and hollow axles.

The Council invite communications from the Members and their friends on the preceding subjects, and on any Engineering subjects that will be useful and interesting to the Institution;—also presentations of Engineering drawings, models, and books for the library of the Institution.

The communications should be written on foolscap paper, on one side only of each page, leaving a clear margin on the left side for binding, and they should be written in the third person. The drawings illustrating the communications should be on so large a scale as to be clearly visible to the meeting at the time of reading the communication, or enlarged diagrams should be sent for the illustration of any particular portions.

PROCEEDINGS.

April 25, 1855.

The General Meeting of the Members was held at the house of the Institution, Newhall Street, Birmingham, on Wednesday, 25th April, 1855; William Fairbairn, Esq., F.R.S., President, in the Chair.

The Minutes of the last General Meeting were read and confirmed.

The following Paper, by Mr. Peter Rothwell Jackson, of Manchester, was then read:—

DESCRIPTION OF A NEW MOULDING MACHINE FOR COG AND OTHER WHEELS.

The difficulty that the writer experienced in the course of his practice, in not being able to find wheels for driving machinery exactly suited in form, strength, and speed to the purposes required —(a difficulty that has been extensively felt, notwithstanding the very large and costly stock of wheel patterns existing in this country;) led him some years since to investigate the subject with a view to discover if some mode of construction could be adopted which would enable the founder to make cog-wheels from a simple segment of two, three, or more teeth of any diameter, pitch, breadth, or shape of tooth, without the use of a pattern in the ordinary way.

The result is the machine, a description of which is the subject of the present paper.

The process hitherto adopted for making the best cog-wheels, whether spur or bevil wheels, has been to construct an entire pattern of wood, an exact *fac-simile* of the wheel to be cast, having each tooth formed and shaped upon it with great care. In all cases this involves a considerable expense and time, besides requiring very careful stowage till the pattern is next needed; but in the case of large wheels this becomes a serious consideration, particularly the time required for preparing the pattern, which causes a great addition to the loss and inconvenience occasioned when an accident happens to one of the wheels in a factory, thereby stopping a large portion of the machinery.

It will be seen that the plan now submitted enables the founder to produce wheels in the shortest possible time, and with a degree of accuracy which is quite unattainable in the usual way, in which patterns are often made in a hurry of imperfectly seasoned timber, and are rarely true even for a short time, and unless made from timber that has had years to season, constructed with the greatest care, and carefully stored, soon become valueless altogether.

The proper form of teeth, which in every case should depend upon the dimensions of both the wheels which are to work together, can seldom be obtained in the ordinary way, owing to the great expense of good patterns. This often leads to the adoption of a form of tooth which is but an approximation to that degree of truth which is readily attainable by the plan now submitted.

It has often been found that wheels of the same pitch, and breadth, but from different makers, will on this account not work well together; this difficulty has sometimes been got over by a hand process of chipping and filing, (commonly termed pitching and trimming,) but such a process, besides the great objection in regard to expense, involves the inaccuracy inevitably attaching to hand work, and has also the objection of removing the hardest and best portion of the metal.

The nearest approach to accurate construction in this direction was, the writer believes, the attempt (formerly made by Mr. Brunton, of Soho,) to shape the teeth by a slotting machine, the tool of which was guided by a templet of the desired tooth.

To obviate the difficulties that have been referred to, the writer conceived the idea of placing in the foundry a machine, on the principle shown in the drawing, by which, as will be seen, he is enabled to produce with great accuracy a short segment of pattern, and also to mould with equal accuracy from the segment thus produced the entire circumference of the wheel required.

Fig. 1, Plate 9, is a vertical elevation of the machine, showing the moulding box and apparatus connected with it, partly in section.

Fig. 2, Plate 10, is a plan of the machine.

Plates 11 and 12 show sections and details.

The machine consists of a vertical spindle A, with a circular horizontal table or face-plate B upon it; this spindle works in the conical bearing formed in the centre of the frame C.

The foot of the spindle A is supported by four diagonal struts DD, extending downwards from the frame C, which support the weight of the table B, and anything that may be put upon it, by means of a foot-step E, by which the table can be raised at pleasure in the conical bearing in the upper frame C, thereby enabling the workman to turn the table round with very little force and perfect steadiness, though bearing great weight upon it.

FF in the elevation and plan is a horizontal slide-bed, attached firmly to one side of the frame C; upon this slide is moved the sliding jib G carrying at its extremity the vertical slide H, a side elevation of which is shown in Fig. 2.

A rack II is attached to the slide-bed, into which works a pinion on the shaft J driven by bevil wheels and the cross handle K. By means of this apparatus the vertical slide H can be placed in any position that may be required over the table B, or may be removed entirely clear from it on either side.

The set screws LL are for the purpose of fixing the sliding jib firmly upon the bed and holding it in any position that may be required.

The vertical slide H is moved by a rack and pinion, worked by a handle and shaft M, and is rather more than counterpoised by a weight T attached to a chain passing over a pulley at the top. A ratchet-wheel with pall, shown in Figs. 5 and 6, Plate 12, is fixed upon the

handle M to hold the slide from being drawn up by the balance-weight, or forced up by the moulder, and the balance-weight is made a little in excess so as to insure a pressure always upwards against the pall of the ratchet.

On the lower end of the slide H, the block of wood out of which the pattern of the teeth is intended to be produced, is fixed by being first screwed to a metal plate, which is bolted to the slide H, being fitted to the plate with vertical and horizontal guides, and having corresponding ribs let into the pattern-block to hold it perfectly steady during the subsequent operations of cutting and moulding, and also affording the means of fixing the pattern true and square upon the plate on any subsequent occasions.

The worm-wheel N is fixed on the under side of the circular table B, and is moved by the worm and shaft O, which shaft is turned round by the handle and change wheels P, similar to an ordinary dividing or wheel-cutting machine.

The worm and worm-wheel are constructed with great accuracy, and are protected from injury and exposure to any dust of the foundry, by a water-lute V, consisting of a vertical ring cast upon the under side of the table and revolving in a small circular trough of water attached to the plate of the lower frame.

By turning the handle P the required number of times, having previously adjusted the change-wheels so as to suit the number of teeth in the wheel intended to be moulded, the circular table B is turned round an interval equal to the pitch of the wheel, and this movement can be accurately repeated in succession through any portion of the circumference.

A block of wood R having been fixed upon the slide H, the slide being adjusted at the required distance from the centre of the table, and the change wheels having been arranged to suit the required number of teeth, a cutter (of which a specimen is exhibited) is fixed in a horizontal spindle, which revolves in a stand fixed upon the main table B. at the correct distance from the centre of the table corresponding to the radius of the intended wheel. This cutter is made to revolve rapidly, and the pattern-block is then

moved down gradually by the vertical slide H, until a parallel cut is obtained through the entire block, forming one space in the pattern. The block is then raised, and by turning the table round the distance of the pitch, and repeating the cut by passing the slide down again before the cutter, another space is formed; which operation is repeated until all the required spaces are cut in the segment pattern. A specimen of the segment is exhibited corresponding to the cutter and block previously shown.

The pattern is made to terminate at somewhat less than half a tooth on each side, and a thin metal shield is fixed on each end in the direction of a radius of the circle, projecting about an inch beyond the crown or point of the tooth, for the purpose of preventing the moulder in the subsequent process of moulding from disturbing the teeth that he has previously formed in the sand. The formation of the short segment pattern R being completed, the cutter and stand are removed, and the moulding box S placed on the table.

In the conical hole in the centre of the table is fitted a bush, in which an upright spindle works, the purpose being for measuring from it the diameter of the wheel, and for strickling or levelling the sand in the moulding box S to form the bottom of the mould of the intended wheel, previous to commencing the moulding of the teeth.

The moulding of the teeth is performed in the following manner:—The segment pattern R is brought down by the slide H until it rests upon the levelled sand forming the bottom of the mould, the top of the segment being level with the edge of the box, and it is there held by the ratchet and pall, and weight.

The moulder then rams up in the ordinary way that portion of the box opposite the segment pattern, and after venting the teeth, removing the pall, he draws the pattern by means of the rack and pinion of the slide H; he then turns the table round by the handle P, through the interval equal to the number of teeth contained in the segment pattern. The pattern is then again lowered, and the ramming up of the mould repeated in the fresh position of the box, and the same process continued until the entire circumference of the wheel is moulded.

In sliding down the pattern into each fresh position, it is pre-

vented from disturbing any portion previously moulded, by its not actually touching the sand, and the shield plates on each end of the pattern prevent any risk of injury in the process of ramming. These plates leave a narrow channel in the sand, causing a small fin on the centre of the crown of the tooth at that position, which is broken and chipped off by the dresser after casting.

The moulding of the cogs (the essential part of the mould) being thus completed, the box can be removed from the machine, and the moulder can proceed with another wheel, whilst other hands place the cores in the mould already formed. The spaces between these cores form the arms of the wheel, and the centre of the wheel is cored out in the ordinary way; the rim of the wheel is formed by the spaces left between the outer extremities of the cores, and the sand forming the teeth, and the boss or nave is formed by the space between the centre core and the inner ends of the cores.

The top box, having the lower edge turned, is rammed up on a true surface plate, forming simply a flat top to the mould, and when placed upon the bottom box, the upper edge of which is also turned, and is on a level with the upper surface of the intended wheel, the sand being strickled off to the edge, forms a perfect joint; and with the cores before named completes the mould for the wheel.

Bevilled wheels are made by the same system on the machine, from a short bevil segment pattern, to produce which a peculiar cutter stand is used, admitting of adjustment to any desired bevil, by which, and the machine, the operator is enabled to impart a correct spacing, and very nearly complete the entire segment. The pattern for a bevilled wheel is lifted vertically out of the sand in the same direction as a spur wheel, and does not slide in the direction of the inclined teeth, on account of the tapered form of the teeth.

Racks can also be made by this machine from a few cogs, by attaching a dividing screw and change-wheels to move the sliding jib and vertical slide H, and fixing the pattern block at right angles to the face of the slide by an angle bracket, so as to mould the rack in a line parallel with the slide-bed.

For moulding very large wheels extending beyond the range of the apparatus, the sliding jib and carriage are removed altogether, and a horizontal arm fixed on the revolving table, carrying at its outer extremity the vertical slide H, and the segment pattern, which are then moved round by the dividing gear, instead of moving the moulding-box, the operation of moulding taking place in a circle round the machine. The cutter-stand for cutting the pattern in this case is fixed upon the ground at the proper distance from the centre of the machine, and the pattern is made to move past the cutter, instead of the cutter moving from space to space of the pattern as before.

The following advantages are experienced in moulding by this machine:—Each wheel being made from a pattern of its own, specially adapted to work into its fellow, and not with reference to any other wheel, the general principle that *any two wheels should have the particular form of teeth that will work best together* can be strictly carried out without difficulty, and at a trifling cost.

The accuracy which has hitherto been with difficulty obtained, even in the best patterns, is by this machine strictly imparted to the sand itself. The teeth, however long or broad, can by means of the slide H, be drawn out of the mould without any taper allowance whatever, and the workman's attention being directed to a few teeth only at a time, he is more likely to give them special care. The time not unfrequently spent in what is called mending the mould, but which in fact, from the difficulty of guiding the hand, is too often found to impair the correctness of the work, is thus saved.

The result is the production of spur and bevil gear of so much greater accuracy than has been produced by other means, that they can be run at a higher speed than has been hitherto considered advisable in heavy gearing.

There is also less need for mortice-wheels, as the noise of gearing proceeds principally from too much clearance, and the want of truth in the teeth.

This plan of moulding allows of H spokes, with flanches round

the inner edge of the rim, being adopted, as readily as the ordinary + or T section of spoke; the H spoke makes a stronger wheel, but is not easily obtained by the old system.

Spur wheels, with shields or flanges to the crown or pitch line, are made with greater facility than by the ordinary process of moulding, as the lower shields are more easily withdrawn, owing to the absence of sand in the centre of the mould.

The large, and in some cases valuable fire-proof buildings, erected for the stowage of wheel patterns, will by the adoption of this process be saved, as one machine gives a greater range of pattern than the largest stock contains.

This method is useful in enabling the founder to match exactly any old wheel, whether the same have parallel or taper teeth, by forming a short segment pattern to work with it with the greatest correctness practicable, and without having to adapt or modify any previous pattern.

It may also be observed that the breakage of a wheel generally implies a deficiency in strength for the work it has to do, but with the old pattern the strength cannot well be increased.

In order to show in how short a time a wheel can be produced by this process, an instance may be mentioned of a spur-wheel, for which the following order was sent to the author, by telegraph, from Bristol, on 1st December last:—

"One spur-wheel, twenty-eight cogs, two feet three diameter at pitch line, cogs two and a quarter long, eight inch broad, six and five-eighths round eye, cast, four arms. Send by rail immediately. Write."

This order was received at the writer's works at 3½ o'clock in the afternoon; the tin templet, steel cutter, and segment to the right size, pitch, and number of cogs, were produced; the wheel was moulded and cast, weighing 6½ cwt.; and after remaining five hours in the sand was taken out and dressed, carted nearly two miles, and forwarded by the Bristol train, which left Manchester at half-past 9 o'clock the following morning, being a total time of 18½ hours; 13 hours being the actual time of making the wheel.

Mr. Jackson exhibited a series of specimens of patterns for spur and bevil wheels made by the machine, from 3/8 inch to 4½ inc pitch, and extending to 16 inches in breadth, with the steel cutter used for forming the teeth of one of the patterns, and the tin templet from which the cutter was shaped; also a cast wheel 2 ft. 3 in. diameter that had been moulded on the machine.

He explained that after having moulded the teeth of a wheel, the further completion of the mould by inserting the cores for the centre and arms could either be done on the machine or after the box was removed, as might be most convenient; sometimes the wheel had been cast whilst the box remained on the machine, but generally the box was removed as soon as the teeth were moulded, to allow another wheel to be proceeded with, and four or five wheels were sometimes on the floor at once, ready for casting at night, all moulded by the one machine during the day. The core-box for the arms was simple in construction, being made with two sides only, fixed at the required angle, determined by the number of arms, and having an adjustable end and bottom, to suit the different diameters and breadths of wheels.

The Chairman said he had seen the machine at Mr. Jackson's works, and was much struck with the great accuracy with which the moulding of the teeth was accomplished, the motion of the slide being quite parallel and steady, so that the pattern was drawn out without risk of disturbing the sand. Before seeing the machine he feared some practical difficulty in insuring accuracy of the pitch at the several joinings of the pattern, but this was completely provided for, by the whole movement of the table, both in moulding and in cutting the pattern, being given by the same dividing wheel, which could be constructed with any required degree of accuracy. The machine appeared an excellent mechanical arrangement for obtaining a degree of accuracy in the sand, superior to the ordinary process of moulding; and he thought the work must be truer than in any wheels cast from a pattern built up of pieces.

He inquired what was the velocity of the cutter employed in forming the segment pattern, and whether the cutter finished the pattern sufficiently smooth for use.

Mr. Jackson replied that the cutter was driven at about 1000 revolutions per minute, and the teeth of the pattern were completed at once by the cutter, and not touched by hand, except what was requisite for varnishing the pattern, which was done to protect it from injury by moisture. The cutter was driven by a cord, stretched tight by a sliding pulley and weight, to allow for the different positions upon the table required for cutting patterns of different diameters.

The Chairman inquired how the cutting of bevil wheel patterns was managed on the machine.

Mr. Jackson explained that a cutter shaped for the small end of the teeth was used in the same manner as in cutting the patterns for spur wheels, except that the pattern-block was held stationary and the sliding motion given to the cutter, in a direction corresponding to the inclination of the cone of the intended wheel, by an adjustable slide. The same slide could also be adjusted to carry a second cutter, revolving at right angles to the main cutter, which would finish the ends of the teeth, by cutting them off at proper angles to the face, and at the required length, the cutter-frame being made to travol round with the circular table. The teeth of the pattern were thus pitched out accurately by the machine and finished at the small ends; and the spaces removed by the cutter were then widened and deepened to a uniform taper towards the other or large ends of the teeth, these large ends being first accuratoly marked out by placing instead of the first steel cutter a tin templet accurately fitting into its place and shaped to the correct form for the large ends of the teeth; this templet was then brought down upon each space of the segment pattern in succession, by means of the dividing wheel, and the exact pitch and outline of each tooth carefully scribed from the templet.

Mr. Hodgkin asked whether the teeth of the pattern were dressed by hand to the required taper.

Mr. Jackson said that some part of the work of shaping the teeth in bevil patterns only was done by hand, but the accuracy of the pattern was not affected, as the man had only to dress them off to a straight edge between two given points, since the teeth were

accurately pitched and cut complete at the smaller end by the machine, and the position of the templet employed for marking out the larger end of each tooth must in each case truly coincide with the previous position of the cutter in forming the small end of the tooth, on account of the same movement of the dividing wheel of the machine being employed for the purpose in both cases.

The Chairman suggested the adoption of some different arrangement of cutter, to enable the tapered teeth to be entirely shaped by the machine, as it was advisable to avoid, if possible, any dependance upon hand work in forming the pattern.

Mr. Ramsbottom observed that the curve of the tooth in a bevil wheel being different at every portion of its length, on account of the whole tooth being tapered both in breadth and depth, caused the difficulty in cutting it by machinery, as no cutter could be passed through in the ordinary way, except the one fitting the small end of the tooth.

Mr. Jackson said that an ingenious arrangement had been made by Mr. Bodmer, to shape the teeth in bevil wheels by means of a long conical cutter revolving on an axis parallel to the teeth, instead of at right angles to them, and pointing always truly to the apex of the cone of the wheel, the outer end being guided to the required shape of tooth by an enlarged templet. Such a cutter might give a pretty correct form to the teeth throughout their length, if the true taper of the sides of the cutter to the centre of the cone could be always maintained; but in his opinion there were great practical difficulties in its application.

Mr. Fernie inquired the expense of moulding by the machine, as compared with the ordinary mode of moulding cog wheels, when there was a pattern already made.

Mr. Jackson replied there would be little difference; his bevil wheels moulded by the machine were about the ordinary price, and spur wheels rather under; spur wheels were supplied by him then at about 13s., and bevil wheels at about 17s. per cwt. In using the machine it was unimportant whether the pattern had to be made or not, as the cost of a segment pattern was very small: the smaller sizes were produced for about 3s.6d. each, including the cutter.

Mr. Fernie inquired what plan was followed in determining the form of curve for the teeth. He thought the machine appeared one of so much importance, and gave such facility for the correct formation of the pattern, that the advantage of the best theoretical form of tooth might be obtained in all the wheels, without regard to existing patterns.

Mr. Jackson said he made any form of tooth that might be desired, and often had to form a special shape in the case of making a wheel to replace an old one, the teeth of the new wheel being modified so as to accommodate it in the best manner that was practicable to the actual form of teeth of the fellow wheel with which it had to gear.

The Chairman suggested that the form of teeth recommended by Professor Willis, and so completely worked out by him, might be advantageously adopted, and the machine certainly gave an important superiority in enabling wheels to be cast with the form of teeth best adapted to the particular purpose for which each wheel was required, without being confined by the limits of ordinary patterns.

Mr. Jackson said the plan he adopted for the form of the teeth, when left to himself, was one suggested to him by Mr. Bodmer, which was to employ true epicycloid teeth, by cutting wood templets to the curves of the particular circles in each case, and rolling them upon one another, tracing the true curve by a steel point attached to the one circle upon a tin templet fixed upon the other; the true curve for a single tooth was thus obtained without hand-work, or the usual approximation by arcs of circles, and the steel cutter was then accurately fitted to the outline traced on the tin templet, this being in fact the only hand-work in the whole process; the subsequent action of the machine insured a perfect copy of the form of the cutter in every tooth.

Mr. Hawkes thought the machine was very ingeniously contrived, and would certainly produce very accurate work: he wished to know whether the time required for moulding the wheels was any longer than by the ordinary process.

Mr. Jackson replied that the time of moulding was about the same in the case of small wheels; the teeth of a 3 feet wheel, either

spur or bevil, would be moulded in about three hours by the machine. In the case of large wheels, the moulding might be done quicker with an entire pattern than by the machine, by several sets of men being employed at once round the wheel; but in the use of the machine, an important saving of time was found in practice from the circumstance that the necessity for mending the mould was avoided, which often caused considerable delay in the ordinary moulding, and however skilfully performed, the repaired part could never be so satisfactory as the rest of the mould.

Mr. Hawkes asked whether in the case of a large number of wheels, say 100, being ordered from the same pattern, it would be considered preferable to make an entire pattern, or still to mould them with a small segment; and suggested for such cases the applicability of a modification of the machine, adapted to draw the whole pattern at once, in a similar manner to the plan adopted with the segment pattern.

Mr. Jackson said such a case had not occurred at present, as the machine had been mostly employed for making single wheels; but in such a case, a larger segment of the pattern might probably be employed, or even an entire pattern, if the wheel were of moderate size. A machine might doubtless be made to lift any sized pattern, but there would be great difficulties in carrying it out practically, and with the present machine the process of moulding the teeth was so simple and certain that it was effected with great rapidity; the moulding could be done with a segment of a single tooth with equal accuracy, but time would be lost, and the general practice was to have from three to seven teeth in the pattern.

The Chairman inquired what time the machine had been in operation since first starting, and how much work it had done.

Mr. Jackson said it had been in work for eight or nine months, and about 170 spur and bevil wheels had been moulded upon it; the machine was now in constant work, and two improved machines, similar to the drawings exhibited, were also being made, to work in his foundry.

Mr. Hawkes inquired whether any of the wheels moulded by the machine had been put to work in the neighbourhood of Birmingham.

Mr. Jackson was not aware whether any had been used in that district; most of the wheels had been made for millwrights and others, who were not able to get wheels to replace broken ones; from not being able to find suitable patterns, they had then sent for wheels moulded by the machine, to prevent the serious delay involved in making a new pattern; the saving of time was found very important in the case of the breakage of large wheels in mills, as they were enabled to replace the wheel and start the mill again in two or three days, instead of sometimes having a delay of nearly as many weeks.

Mr. Hawkes remarked that a difference in ramming the teeth was sometimes experienced; some being rammed softer than others, causing a little irregularity in the casting by the yielding of the softer teeth; and inquired whether any difficulty of this kind was experienced in the moulding by the machine.

Mr. Jackson said he had found some cases of the kind, though very rarely; and they were safer from that risk with the machine than in the ordinary process of moulding, on account of the uniformity and regularity with which all the teeth were successively rammed; the moulder having to ram and complete only a few teeth at a time, they received more attention.

The Chairman inquired what increase of speed was anticipated by Mr. Jackson, as practicable in heavy gearing, in consequence of the superior accuracy in the teeth of the wheels moulded by the machine.

Mr. Jackson thought it was very difficult to assign a limit to the speed, if the teeth of the wheels were really accurate; he thought a velocity of 5000 feet per minute might be attained in the circumference of heavy wheels, with the improved teeth obtained by the machine. He had found very considerable increase of speed practicable in many cases where new wheels moulded by the machine were substituted for old ones that had broken; in a rolling mill he was acquainted with, some of the old wheels had about $\frac{3}{8}$ths inch clearance, and badly-shaped teeth, and when he had put some new wheels moulded by the machine into their place, a great difference in the smoothness of the motion was experienced. He was confident the great imperfection in the teeth caused

in some cases an irregularity to be communicated to the motion, and a serious loss of power in heavy machinery; and a much higher speed might be safely attained by proper construction of the teeth than was generally considered practicable. He had been much struck by seeing in a spinning mill, at Alsace, in France, the whole of the self-acting-mule spindles, which were running at 4000 revolutions per minute, driven by cog wheels in place of bands; there was of course a shrill sound in the rooms from so many thousand wheels, but there was no excessive noise such as to prevent the voice being heard. He was convinced by the examination of that machinery, that accuracy of construction in the teeth was alone wanted to render practicable with cog wheels any speed likely to be required in machinery. These wheels were of iron, cast from metal patterns very carefully made.

Mr. Hawkes asked whether it was found requisite to rap the pattern whilst drawing it up from the mould, to prevent the sand adhering to it. He suggested the use of a metal plate laid on the top of the sand to keep it down, the plate fitting in only roughly between the teeth.

Mr. Jackson said that the pattern was rapped gently during the time of drawing it up, by striking with a light hammer on a block of wood held upon the top of the pattern; this was found quite sufficient for the purpose, and it was a very rare occurrence that any injury of the mould was caused by the sand adhering to the pattern, and he did not think that any other provision was required for the purpose. He had anticipated that some difficulty might occur in this respect, but was surprised to find the clearness with which the pattern drew from the sand; the pattern being made very true and smooth by the cutter from the rapidity of its revolution, and then polished with varnish, it parted readily from the sand. The patterns were all made of bay-wood very well seasoned, and being only small were not exposed to injury like ordinary patterns; the same pattern he expected would serve for moulding many wheels before even requiring re-varnishing.

Mr. Ramsbottom said he had seen the machine in operation, and there appeared to be no difficulty in drawing the pattern

without injury of the mould, on account of the teeth being perfectly parallel and vertical. This correctness arose from the circumstance, that the pattern was *cut* in the same position in which it was *moulded*, and by means of the same sliding movement that was afterwards made use of to draw it out of the sand; and consequently the motion must be absolutely parallel to the face of the pattern; any inclined position of the slide would cause the pattern to be cut and also drawn from the sand at exactly the same inclination. The action of the machine was certainly very perfect and satisfactory, and it appeared to be very successful in its operation.

Mr. Hawkes inquired what sand was used for moulding the cog wheels, and whether it was found necessary to employ any superior quality to insure the teeth being cleanly moulded.

Mr. Jackson replied, that road sand was principally used for heavy castings; the ordinary red sand of the district would not stand the heat sufficiently by itself, except for light castings. Road sand was very generally used in the neighbourhood of Manchester for foundry work, mixed with the other sand in different proportions according to the description of the castings, and was found to be well suited for the purpose.

The Chairman observed that the road-sand or road-sweepings in the neighbourhood of Manchester was obtained in great quantities, and was very uniform and clean in quality. The very best of this sand for foundry purposes was obtained in a particular district, extending between Rochdale and Halifax, where the sandstone grit was pulverized very fine by the constant action of the cart-wheel traffic; this sand was used very extensively for lining the cupolas, as it resisted an intense heat without fluxing.

Mr. Ramsbottom remarked that the very open nature of the grit-sand probably accounted for the advantage experienced in using it for moulding, as it would afford greater facility for the escape of air in heavy castings than the ordinary moulding sand alone.

The Chairman said the machine appeared to be a very ingenious and successful improvement in the process of moulding cog-wheels, and of great practical importance; he proposed a vote of thanks to Mr. Jackson for his communication, which was passed.

The following Paper, by Mr. John Fernie, of Derby, was then read :—

ON AN IMPROVED TUYERE FOR SMITHS' HEARTHS.

The subject of an improved construction of Water Tuyere, invented by Mr. John Lee, was brought before the last Meeting of the Institution, and the writer of the present paper, as the successor to Mr. Lee, at the Britannia Foundry, Derby, where the first trials were made, has the pleasure of adding some further particulars of the invention, which appears to have been original on the part of Mr. Lee, though also independently invented by some other parties.

His first design was a hollow cast-iron tuyere, shown in Fig. 1, Plate 13, and similar to those ordinarily made in wrought iron; of these one or two still continue in use. There was some difficulty in getting the air out of the core; and the next step to remedy this is shown in Fig. 2, where DD is the tuyere, and E a cover plate attached with bolts, a pasteboard joint being placed between, and the ascending and descending pipes are secured in this cover plate. This makes a very good tuyere, cheap, and easily replaced, and some of them have been in use three or four years, and do well.

The next step in the invention was the tuyere described in the paper read at the last Meeting.

The writer understands that a similar construction of tuyere was introduced by Mr. James Galt, into Messrs. Scott and Sinclair's Works, at Greenock, in 1847, which appears to have been his own independent invention; and from the satisfactory manner in which these have worked, Messrs. Neilson, of Hyde Park Foundry, and other engineering establishments of Glasgow, have adopted them.

The method employed at the Britannia Foundry, in casting these tuyeres, is to cast first the inside piece FF, Fig. 3; a dry sand core is then made in the space of the GG pattern, and the inside piece is rammed up in the lower box; the outside pattern being then put fairly on it, the mould is completed. The pattern being now withdrawn, the dry sand core is slipped on the inside piece, and the mould is then ready for casting; the outside is thus shrunk upon

the inside piece, and the latter being slightly ridged at the junction, they are rendered perfectly tight, and are seldom or never found to leak. They also stand the fire well, and the moulding being thus simplified, these tuyeres are made cheaply.

Figs. 4, 5, and 6, Plate 14, show a double hearth having this tuyere combined with it, and of a class of which many have been made, and have been found to answer well. It is constructed entirely of cast-iron, and the advantages of cast-iron hearths over brick hearths are their portability, the comparatively little space they take up, which is further economised by the plan of bent tuyere shown in the drawings; also their compact form, which allows the shop foreman to overlook at once all the men in the shop. These hearths are also cheaper than brick ones, and the depth being less, the tuyeres are shorter.

Mr. RAMSBOTTOM inquired whether any practical difficulty had been experienced from leakage at the nozzle of the tuyeres? as the two portions were not united, but only cast one upon the other.

Mr. FERNIE said he had not found any leakage to take place; a large number had been made upon the plan as shown in the drawings, and they had proved quite satisfactory. At the last meeting another plan of construction had been shown, with a turned cone joint at the nozzle, but he had not found any occasion for such a joint; the plan of casting the outer portion upon the inner one, he had found to make a practically tight joint by the contraction in cooling, and it was a cheaper mode of construction.

The CHAIRMAN asked how long the tuyeres had been at work, upon the make shown in the drawings?

Mr. FERNIE replied that a large number had been in use upon that plan for five or six years, and most of them had been in constant work all the time without requiring repair.

The CHAIRMAN then proposed a vote of thanks to Mr. Fernie for his communication, which was passed.

The following Paper, by Mr. Edward E. Allen, of London, was then read :—

ON THE COMMERCIAL ECONOMY OF WORKING STEAM EXPANSIVELY IN MARINE ENGINES, WITH DESCRIPTION OF A NEW DOUBLE EXPANSIVE MARINE ENGINE.

It is proposed in the present paper to consider the practical or commercial advantages of working Steam expansively in the Marine Engine, as distinguished from the theoretical advantages, which latter are better understood, and more generally admitted.

It has been established theoretically, that considerable economy is obtainable by working steam expansively. Thus—if steam be allowed to occupy or expand into twice the space it originally occupied, the power developed would be as 1·7 to 1, and according to the following table :—

Spaces occupied by steam	1	2	3	4	5	6	7	8	9	10
Power developed	1	1·7	2·1	2·4	2·6	2·8	3·0	3·1	3·2	3·3

The same volume of steam being used in all cases, and allowed to occupy the increased spaces during expansion.

Notwithstanding that this has been long known, it has only been comparatively recently, that practical benefit has been derived to any considerable extent from working steam expansively, and even at the present day the principle is but imperfectly recognised, or at least is very inadequately carried out in practice.

The attention of the Institution has been called, on several occasions, to the advantages of working steam expansively, both in Engines employed in Manufactories, and in Mining Works, and also in Locomotives; and the papers of Mr. Fairbairn, Mr. Samuel, and Mr. Clark, have taken up the subject in reference to those particular cases.

The object of the present paper is confined to the advantages of working steam expansively in *Marine Engines*, and to endeavour to arrive at the causes which have hitherto prevented the principle from being as successfully carried out and as productive of economy as in the case of pumping or other Stationary Engines.

It would almost seem that the apparent necessity of making the engines of Steam Vessels occupy the least possible space, actually prevented, for a very long time, any attempt whatever being made to economize fuel; everything being overlooked or considered unimportant, when compared to the supposed advantage of having the engine space as small as possible.

It was very natural that the first step in the economizing of fuel, by working steam expansively, should be taken in places where the spaces which the engines occupied could be almost indefinitely increased; and we find, consequently, that the system of working expansively, made very great progress, and may almost be said to have been perfected in Pumping and Winding Engines, before its value was at all recognized in other cases. Pumping engines had been worked on the expansive principle for some time, before any attempt was made to carry it out in engines employed in the Manufacturing districts, this being chiefly owing to the cheapness of coal, and the consequent disregard of economy, and also to the circumstance of a more uniform motion being required.

It will be seen that in the case of engines of manufactories, the ground space was but little more limited than in the case of pumping engines, and probably quite as little limited in respect to vertical height. The boiler-room in these cases was also almost unlimited, as also was the weight of the machinery, and it was not until the principle of expansion was considered with reference to Marine Engines and Locomotives, that the objections to increased bulk and weight of the machinery became, or appeared to become, so important, as to prevent its being carried into practice.

One very important matter appears to have been overlooked in considering the weight of the Marine engine, and that is, that it is not simply the weight of the Machinery that has to be considered, but the joint weight of the machinery and fuel. It is true that in the case of the first steam-boats, the weight of the fuel carried did not form so important an item as at the present time; yet as compared to that of the engine and boiler, it was, and always must be, considerable in every steam vessel. In river boats it may be taken roughly at about one quarter the entire weight of engines, boilers, and water, equal to about $2\frac{1}{2}$ days' consumption, this being the least proportion.

The following Table gives the weight of coals usually taken by steamers, according to the length of voyage, &c. :—

TABLE I.

Proportion of Weight of Coals to Weight of Machinery.

Class.	Service.	Station, or Employment.	Number of Days' Consumption.	Proportion of Weight of Coals to Weight of Machinery.
1	River	Thames and Clyde	2½	¼th.
2	Coasting and Continental	General Steam Navigation Company, Colliers, &c.	10	Equal.
3	Ocean, Short voyages	America and Government	15	1½ times.
4	Ocean, Long voyages	Australia	40*	4 times.
5	Ocean, proposed voyage out and home	India, &c.	70	7 times.

It will thus be seen that, except in River Steamers, any saving in the quantity of fuel must be of vital importance, and the more so, in proportion to the length of voyage.

In the large steamer now constructing for the Eastern Steam Navigation Company, the quantity of Coals taken is proposed to be seven times the gross weight of Machinery, so that any small per-centage of saving would really amount to a considerable quantity.

On one occasion the "Crœsus" took nearly 1400 tons of coals, being about in the proportion of 7 to 1 to weight of Machinery. This quantity was intended to work her outward and part of her homeward voyage.

It will be found that, as a general rule, Marine Engines are only using their steam expansively to a very small extent, the steam usually being cut off at 3-4ths of the stroke, thus economising in the ratio of 1·3 to 1 only, or say practically equal to a saving of 20 per cent. on the coal consumed if no expansion were allowed to take place.

This amount of expansion is given by the slide alone having suffi-

* Steamers taking coal equal to only four times the weight of machinery, are obliged to coal on the way out and home.

cient lap on the steam side. It is now usual however to fit expansion valves to the Government engines, as well as to many in the Merchant service, for the purpose of working expansively when short of coal, or when the vessels are running with a fair wind; but these appliances are never designed for continual working. The "link motion" is also used in marine engines for occasional expansive working.

From a pamphlet recently published by Capt. J. C. Hoseason, lately commanding the "Inflexible," it appears that so far back as 1842 the attention of the Admiralty was called to the subject now in hand, viz.:—the economy of expanding steam. But at that time the principal difficulty in using steam expansively was doubtless the low pressure at which the boilers were worked, being only about 5 lbs. per square inch.

It appears however that in 1842 the pressure in the boilers of the "Inflexible" was raised from 6 to 8 lbs. by Capt. Hoseason's desire, and the pressure in the "Terrible" was fixed at 10 lbs.

In 1849 the Indian Government obtained a paper on the expansive action of steam from Messrs. Maudslay, Sons, and Field, and from the extracts given in Capt. Hoseason's pamphlet, it would appear that the case was fairly made out.

To prove the extent to which the *weight of the machinery* could be increased without increasing the *gross weight* carried, the following example is given.

"Suppose a vessel with 400 horse-power engines working up to their full power; the consumption would be 30 tons per day, and she would carry 750 tons of coal, which would be 25 days' consumption.

The 400 Horse engines would weigh	. 300	tons.
Coal	. 750	„
Total weight	1050	„

"Suppose the same vessel with 600 Horse engines, but only working up to 400 Horse-power, the consumption would then be 22½ tons per day, and she would carry 600 tons of coal, which is 26⅔ days' consumption.

The 600 Horse engines would weigh	. 450	tons.
Coal	. 600	„
Total weight	1050	„

"Thus, with the larger engines, the vessel will carry 1½ days' more coal than with the smaller engines, and would save during 25 days the value of 150 tons of coal."

These facts having been pointed out so forcibly six years ago, it appears strange that the principles upon which they were founded should not have been carried out more fully than they have been. Comparatively, however, nothing has been done, although with respect to the Australian Vessels, the necessity of economising has increased three-fold, from the quantity of coal required to be carried being just about three times that taken by the Government vessels, viz., about 4 times the weight of machinery, instead of 1½ times. It will be seen that as the necessity for economy increases, so does the facility or means of producing it increase, from the great proportionate weight of coal upon which a reduction can be made, in order to compensate for any increase in the weight of machinery.

In such cases as the Australian Vessels, where the weight of coals carried amounts to 4 times the weight of machinery, a saving of 25 per cent. of the coals would allow of the weight of the machinery being doubled, without the gross weight being increased.

Take for example Engines of 400 Horse-power, weighing 300 tons, and the coals carried, 1200 tons, making a total of 1500 tons. If the coals by more economical working can be reduced to 900 tons, then the engines may be allowed to weigh 600 tons, and the gross weight to be carried will only be the same, the coal saved being equal to 300 tons. Extending Messrs. Maudslay's example, it will be seen by the following Table 11. to what extent the weight of the machinery could be increased without adding to the gross weight, in the case of the coals carried being equal to 4 times the weight of machinery, the power worked up to being the same.

TABLE II.

Showing the increased weight of Machinery caused by increasing the nominal horse-power or size of the engines, and also the necessary reduction in the quantity of coals taken, so that the gross weight may remain the same.

Power Worked to	Nominal Horse-power.	Weight of Machinery.	Weight of Coals.	Total weight carried.	Consumption per day.	Number of days' Consumption.
H.P.	H.P.	Tons.	Tons.	Tons.	Tons.	Days.
Full.	400	300	1200	1500	30	40
400	600	450	1050	1500	$22\frac{1}{2}$	45
400	800	600	900	1500	20	45
400	1000	750	750	1500	19	40
400	1200	900	600	1500	18	35

From this it seems that an increase in the weight of machinery to $2\frac{1}{2}$ times, still admits of coals sufficient to work for as many days, and saves 450 tons of coal.

The object of the present paper is somewhat different from that aimed at in the pamphlet referred to, although nearly the same considerations are involved. It was then desired to show that both the power and weight of the engines could be increased without increasing the gross weights carried, the increased power being only occasionally used—this being a most important point for War Steamers, and others, when working against the hurricanes in the Indian seas, &c. This advisable increase of power, however, involving a corresponding increase in the first cost of engines, though attended with counterbalancing advantages.

It is proposed now to show how the *engines alone may be increased* in size for expansive working, and consequently slightly increased in weight, not only without increasing the gross weight carried, but how it can be done so as very materially to *lessen the gross weights* carried, that is in coal and machinery, leaving greater stowage for cargo.

It is presumed that the power placed in vessels is now sufficient (whether it is so or not does not affect the present question), and therefore in the examples given, no provision is made for the engine power

being even temporarily increased, although this would probably, in many cases, be a great desideratum. Neither are the Boilers supposed to be increased, either in number or size; but to avoid complicating the deductions they are supposed to remain the same, especially since at present marine boilers are too much overworked to last any length of time, and an increase of boiler room relative to the power would be desirable. Strictly considered, however, the weight of the boilers would be diminished in about the proportion of the diminution of coal consumed.

Taking the five classes of steamers given in the preceding Table I., which shows the weight of coals usually taken in the several cases, it will now be necessary to give the spaces occupied by them in proportion to that occupied by the Engines, exclusive of the boilers and passages. The following Table, III., shows the floor or horizontal space occupied by the Coal-bunkers in the five classes of steamers.

The Engines, Boilers, and Water are supposed at 13 cwt. per HP. *
The space occupied by Coals is taken at ... ... 45 cub. ft. per ton.
The floor space occupied by Engines alone is taken at $\frac{3}{4}$ sq. ft. per HP. †

TABLE III.

Proportion of space occupied by Coals to that occupied by Engines alone.

Class.	Station or Service.	Weight of Coals, in terms of weight of Machinery.	Depth of Coals in each Class of Vessel, approximate.	Horizontal or floor space occupied by Coals, in proportion to Engines alone.
1	River.	1-4th.	9 feet.	Equal.
2	Coasting and Continental.	Equal.	12 feet.	3 times.
3	Ocean Short Voyages, and Government.	$1\frac{1}{2}$ times.	20 feet.	3 times.
4	Ocean Long Voyages.	4 times.	25 feet.	5 times.
5	Ocean Proposed Voyage out and Home.	7 times.	50 feet.	5 times.

It will be seen from the above table, that in the case of Government vessels, where the weight of coals is usually equal to $1\frac{1}{2}$ times the gross weight of machinery, the horizontal space occupied by the coal may be taken at 3 times the space taken up by the Engines themselves

* See Table IV. † See Table VII.

(that is, exclusive of boilers and passages), or about equal to the total machinery space, if the boilers and passages be included. This is further explained by Table VI., which gives the examples from which these data are obtained.

In the example quoted above from Messrs. Maudslay, where the coal weighed $2\frac{1}{2}$ times the machinery, instead of $1\frac{1}{2}$ times which is the quantity more generally taken, the horizontal or floor *space* occupied would be 5 times that occupied by the engines alone, instead of 3 times as given above. So that supposing the passages left the same, the 400 horse-power engines could be replaced by engines of 600 horse-power, and the saving of space required for coal would balance the increased space occupied by the engines, consequently leaving the total weights carried the same, and the total space occupied by machinery and coal (taken together) the same, with the 600 horse-power engines, as with the 400 horse-power.

The following Table IV., is given for the purpose of showing the relative weights of the different parts of the machinery in steam vessels, and is taken from two tenders supplied to the Government for paddle-wheel engines of 260 horse-power, and screw engines of 450 horse-power; the Table shows also the average of 18 estimates sent to Government by different engine-makers, giving the separate weights of the various parts of the machinery (as the engines, boilers, water, wheels or screws, &c.)

TABLE IV.

Parts.	Paddle Engines, 260 horse-power.	Screw Engines, 450 horse-power.	Paddle Engines, Average of 18 Estimates, 453 horse-power.	General average per horse-power.
Engines	80 tons.	127 tons.	127 tons.	5·70 cwt.
Boilers and fittings	45 „	55 „	63 „	2·95 „
Water	30 „	45 „	$42\frac{1}{2}$ „	1·90 „
Coal-bunkers	10 „	15 „	$15\frac{1}{2}$ „	·70 „
Wheels	13 „	30 „	$28\frac{1}{2}$ „	1·20 „
Spare Gear	12 „	18 „	$16\frac{1}{2}$ „	·75 „
Total	190 tons.	290 tons.	293 tons.	13·20 cwt.

It will be sufficiently near for the present purpose, therefore, to

consider the relative weights of the different parts of marine engines to be as follows, viz.:—

Engines	$5\frac{1}{4}$ cwt.	per nominal horse-power.
Boilers and fittings	3 cwt.	" "
Water	2 cwt.	" "
Wheels or screw	1 cwt.	" "
Spare gear	$\frac{3}{4}$ cwt.	" "
Coal-bunkers (containing about 15 cwt. per horse-power.)	$\frac{3}{4}$ cwt.	" "
Total	13 cwt.	per nominal horse-power.

The practical applications which are made of these particulars in the calculations contained in this paper are, first, that the weight of marine machinery may be fairly assumed at 13 cwt. per nominal horse-power; and secondly, that the weight of the engines and spare gear together may be taken at *one half* of the gross weight of machinery. This consideration is of much importance, as it is the engines alone that are supposed to be increased in size and weight, to admit of greater expansion of the steam; the boilers and wheels or screw being supposed to remain the same, as has been before stated.

Table V. gives the total space occupied by the Machinery and Coals relatively to the entire hulls, and includes the averages of six vessels with side-lever engines, and six vessels with direct-acting engines, all belonging to the Peninsular and Oriental Steam Navigation Company; also the average of 1200 English Merchant vessels.

TABLE V.

Average Registered Tonnage.	Average Tonnage of Engine-room.	Average Total Tonnage.	Average Horse-power.	Per-centage of Engine Room to total tonnage.	Average total Tonnage, per Horse-power.
Average of 6 Side-lever Engines, P. and O. S. N. Co.					
1156	913	2069	636	44 per cent.	3·25
Average of 6 Direct-acting Engines, P. and O. S. N. Co.					
1659	854	2513	794	34 per cent.	3·16
Average of 1200 English Merchant Steamers.					
138	108	246	83	44 per cent.	2·95

TABLE VI.

No.	Name of Vessel.	Screw or Paddle.	Tonnage.	Horse-power.	Assumed Weight of Machinery at 13 cwt. per horse-power.	Tons of Coal carried.	Weight of Coal per horse-power.	Total Engine-room (Including Coals.) Length.	Beam.	Depth.	Horizontal area.	Horizontal area per horse-power.	Bulk of Coal, 45 cubic feet to the Ton.	Assumed depth of Coal in Bunkers 4/5ths of Engine-room.	Horizontal area of Coal space.	Horizontal area of Coal per horse-power.
					Tons.	Tons.	Tons.	ft. ins.	ft. ins.	ft. ins.	sq. ft.	sq. ft.	cubic ft.	feet.	sq. ft.	sq. ft.
1	Termagant . .	Screw	1,547	620	403	280	·45	85 0	39 4	25 9	3,343	5·39	12,600	20	630	1·01
2	Bosphorus . .	Screw	536	80	52	150	1·87	30 0	25 0	16 6	750	9·37	6,750	13	520	6·50
3	Terrible . . .	Paddle	1,847	800	520	800	1·00	78 7	38 0	27 4	2,986	3·73	36,000	22	1,636	2·04
4	Odin	Paddle	1,326	560	364	445	·79	60 0	34 4	20 0	2,060	6·67	20,025	16	1,251	2·23
5	Asia	Paddle	2,130	800	520	900	1·12	92 6	40 6	27 6	3,746	4·68	40,500	22	1,841	2·30
6	La Plata. . .	Paddle	2,403	1,000	650	1,200	1·20	82 9	40 8	27 8	3,365	3·36	54,000	22	2,454	2·45
7	Proposed Australian, direct	Paddle	3,188	800	520	1,500	1·87	72 0	45 0	32 0	3,240	4·05	67,500	26	2,596	3·24
	Averages		1,854	666	433	754	1·14	71 7	37 7	25 3	2,690	4·04	33,911	20	1,695	2 54

TABLE VII.

Name of Vessel.	Name of Engineer.	Description of Engines.	Screw or Paddle.	No. of Cylinders.	Diameter of Cylinders.	Length of Stroke.	Horse-power.	Length of Engine (fore and aft)	Breadth of Engines	Area of floor space.	Height above centre.	Area of floor space per horse-power.
					Inches.	Ft. In.		Feet.	Feet.	Sq. ft.	Feet.	Feet.
Simoom	Watt and Co...	Horizontal oscillating	Screw	4	44	2 6	350	13	16	208	3	·59
Niger	Maudslay	Do. short connecting rod	Screw	4	47⅝	1 10	400	15	16	240	3½	·60
Arrogant, &c.	Penn	Do. trunk	Screw	2	55	3 0	360	11	24	264	3	·73
Conflict	Seaward......	Do. short connecting rod	Screw	4	46	2 0	400	20	21	420	2¾	1·05
Vulcan, &c.	Rennie	Do. do. do.	Screw	4	49½	2 0	350	13½	17½	236	3¾	·67
Frankfort	Thompson	Inverted vertical ..	Screw	2	40	2 10	100	11	14¼	157	12	1·57
Pomone	Holm	Horizontal steeple	Screw	2	46	3 10	220	15½	21	326	3½	1·48
Minx	Seaward......	Do. short connecting rod	Screw	2	..	..	10	7	7¾	54	1	5·40
Retribution	Maudslay	....	Paddle	..	..	..	800	23½	24	554	..	·69
Thunderbolt	R. Napier ...	....	Paddle	..	..	..	300	15¾	17½	275	..	·91
Vulcan	Fairbairn	Direct acting	Paddle	2	80⅝	5 9½	476	12¼	19½	239	..	·50
Black Eagle	Penn	Oscillating	Paddle	2	62	4 6	260	10¾	21½	231	..	·88
Amazon	Hick	....	Paddle	..	..	..	300	16	17½	280	..	·93
Clyde, Tay, Tweed, &c	Caird	Side lever	Paddle	2	..	..	460	27	23½	634	..	1·37
Averages	....	....	.. .	..	..	..	342	15	19	285	..	·83

From Table V. it appears that from 34 to 44 per cent. of the *whole capacity* of the Vessels is occupied by the Engine-room and Coals. The Table also gives the most general proportion of power to tonnage as one horse-power to every three tons.

Tables VI. and VII. give the particulars of several steamers, with both screw and paddle-wheel engines, from which the comparative spaces occupied by the Coals and Machinery will be seen.

From these Tables several important particulars may be deduced:—

1st.—That in Government Vessels the general proportion of coal taken is 1 ton per nominal horse-power, equal to about 1½ times the gross weight of machinery, as before given.

2ndly.—That the horizontal space occupied by the entire engine-room, when this proportion of coal is taken, is about 4 to 4½ square feet per nominal horse-power.

3rdly.—That the space occupied by the coal-bunkers, carrying this proportion of fuel, may be taken at 2 or 2½ square feet per horse-power, or about 3 times the space occupied by the engines alone, exclusive of boilers, passages, &c.

4thly.—That the space occupied by the engines alone, exclusive of boilers, coal-bunkers, and passages, may be taken at ¾ square feet per nominal horse-power, that is, where the engines are direct-acting.

From an average of the 18 estimates furnished to Government by different makers, and from some other cases, it appears, that the space occupied by the boilers alone may be taken at about 1 square foot per nominal horse-power, and that the total price of £43 per horse-power for the machinery may be thus divided:—

	£	s.	d.	
Engines, boilers, and coal-bunkers	38	0	0	per horse power.
Wheels	2	10	0	,, ,, ,,
Spare gear	2	10	0	,, ,, ,,
Total . . .	£43	0	0	,, ,, ,,

The amount for engines, &c., may be divided nearly as follows:—

	£	s.	d.	
Engines	24	0	0	per horse-power.
Boilers	12	0	0	,, ,, ,,
Coal-bunkers	2	0	0	,, ,, ,,
Total . .	£38	0	0	,, ,, ,,

These proportions will be quite near enough for the purpose required, and the relation they bear to each other will not be much influenced by the present increased prices.

It will therefore be assumed that the cost of the engines alone is about one half the entire cost of machinery.

It will be requisite further to consider the average *annual expense* of the coal used by steam vessels, and its proportion to the cost of the vessels or capital; this depending partly upon the class of vessel, and partly upon the service upon which she is engaged.

Table VIII. gives an approximation to the yearly cost of coal used by 5 classes of vessels, with the relation it bears to their cost.

These comparisons will be found useful when the advantages of increasing the size of the engines are considered.

The cost of coal in London is taken at 16s. per ton.

The cost of coal in Liverpool is taken at 12s. per ton.

The cost of coal for Australian vessels at an average of 60s per ton.

The cost of coal for Eastern Steam Navigation Company at 12s. per ton.

The price of coal is sometimes above these amounts, but they are near enough to illustrate the argument intended.

For better comparison, it will be desirable to condense the results, and this Table gives us the cost of Engines alone (assumed at half the total cost of Machinery) in

Classes 3, 4, and 5, at 15 per cent. of the capital;
Class 2, . . . at 20 per cent. of the capital;
Class 1, . . . at 30 per cent. of the capital.

Also the yearly cost of Coal in

Classes 2, 3, and 5, at say 5 per cent. of the capital;
Class 1, . . . at say 15 per cent. of the capital;
Class 4, . . . at say 25 per cent. of the capital.

TABLE VIII.

Table of the Quantity and Cost of Coal used, per annum, in different Classes of Vessels, and relation of Cost of Coal to Cost of Vessel, and also to Cost of Machinery.

Class.	Service.	Ratio of time under weigh.	No. of Voyages per annum.	Consumption of Coal per voyage.	Total consumption per annum.	Cost of Coal per Ton.	Total Yearly Cost of Coal.	Assumed Cost of Vessel complete.	Assumed Cost of Machinery alone.	Ratio of Cost of Machinery to Cost of Vessel.	Cost of Engines alone (assumed at half the Machinery) in per-centage of cost of Vessel.	Cost of Coals in per-centage of Cost of Vessel.
				Tons per voyage.	Tons.	s. d.	£	£	£	Per Cent.	Per Cent.	Per Cent.
1	River. . .	$\frac{1}{3}$	—	6	1,800	16 0	1,400	8,000	4,800	60	30	$17\frac{1}{2}$
2	Continental.	$\frac{1}{3}$	40	30	1,200	16 0	1,000	18,000	7,200	40	20	$5\frac{1}{2}$
3	American .	$\frac{1}{3}$	6	1,500	9,000	12 0	5,400	90,000	27,000	30	15	6
4	Australian .	$\frac{2}{3}$	2	2,500	5,000	60 0	15,000	60,000	18,000	30	15	25
5	Eastern Steam Navigation Company .	$\frac{1}{2}$	3	12,000	36,000	12 0	25,000	500,000	150,000	30	15	5

NOTE.—The Royal Mail Steam Packet Company's Accounts for 1850, give the Cost of Coal at 15 per cent. of the Cost of Vessel, and the Cost of Machinery at about 40 per Cent. of the Cost of Vessel, or *Engines alone* at 20 per cent.

In further illustration of this part of the subject, the subjoined accounts are added.

The following account, in Table IX., is given by the West India Mail Steam Packet Company, showing the relative cost of Coal, Wages, &c., for 1850 and 1852; the amounts being the mileage expenses:—

TABLE IX.

West India Mail Co., Mileage Expenses.

	1850.		1852.	
	Per Mile Run.	Per-Centages of Total.	Per Mile Run.	Per-Centages of Total.
	s. d.		s. d.	
Coals	3 10	30·07	5 4	35·55
Wages	2 1	16·34	1 10	12·22
Victualling . . .	1 5	11·11	1 5	9·45
Stores	0 8	5·23	0 8	4·45
General Service .	1 3	9·80	1 5	9·45
Port Charges . .	0 3	1·96	0 4	2·22
Insurance . . .	1 3	9·80	1 7	10·55
Repairs	2 0	15·69	2 5	16·11
Total . . .	12 9	100·00	15 0	100·00

This gives the cost of Coals in 1850, equal to 30 per cent. of the total working cost, and in 1852, equal to 35½ per cent.

Table X. gives the total actual expenses of Coals, Wages, &c., of the same Company, for the year 1850, and the per-centages of these items, on the total cost of Vessels.

This Table gives the cost of Coals in 1850 equal to 28 per cent. of the working expenses, and nearly 13 per cent. of the total cost of vessels, and the whole working expenses at 45½ per cent. of the cost of vessels.

If the mileage working expenses for 1850 be taken to amount to 45½ per cent. of the capital, then in 1852 the same expenses would be 53½ per cent., and from the respective ratios of the cost of coals to the total

working expenses for those years we have 13·74 per cent., and 19·02 per cent. as the cost of coals on the capital; consequently 15 per cent. may be fairly taken as a mean.

TABLE X.

West India Mail Steam Packet Company.

	Working Expenses in 1850.			Per-Centage of Total.		Per-Centage on Cost of Vessels.
	£	s.	d.			
Coals, Freight, & all Charges	88,436	0	7	28·17	Total cost of Vessels £692,249 1 10	12¾
Wages	44,858	13	10	14·29		6¾
Provisions	63,863	9	7	20·34		9¼
Stores	15,387	8	0	4·90		2¼
Port Charges and Pilotage	6,745	0	1	2·15		1
General Service and Stations	13,179	10	5	4·20		2
Coal Sacks	1,927	9	2	·62		¼
Office and Law	1,713	1	8	·55		¼
Salaries	11,730	17	2	3·74		1¾
Insurance	25,000	0	0	7·96		3⅛
Repairs, Ship, & Machinery	41,055	8	10	13·08		6
Total	313,896	19	4	100·00		45⅛ per cent.

For easy reference the following Table XI., is given :—

TABLE XI.

When the Annual Cost of Coal on capital amounts respectively to	5 per cent.	15 per cent.	25 per cent.
Then 10 per cent. saving in Coal equals	½ per cent. on capital.	1½ per cent. on capital.	2½ per cent. on capital.
„ 20 „ „ „ „	1 „	3 „	5 „
„ 30 „ „ „ „	1½ „	4½ „	7½ „
„ 40 „ „ „ „	2 „	6 „	10 „

As the least of these savings, in the middle column, frequently makes all the difference between a good and bad paying concern, it is quite certain that upon the expenses of the single item of coal may frequently hang the very existence of a Company.

It will be seen from the foregoing accounts, that there is little room for economizing the expenditure upon any other item, to anything like the extent possible in the item of coals alone, as the largest amount next that for coals, according to the mileage expenses, is for wages or repairs, each of these amounting to only about half the cost of the coals.

The following Tables XII., XIII., XIV., have been compiled in order to show the increased dividend on original capital which may be made by a saving in coal, owing to expansive working of the steam, the size or nominal horse-power of the engines being supposed to be increased from 1 to 1½, 2, 2½, and 3 times respectively, the extra cost of larger engines being proportionately allowed for, and the boilers and wheels or screw supposed to remain the same. The indicated or real horse-power is also supposed to remain the same, the larger engines being solely for the purpose of working the steam expansively.

The first Table XII. is based on the supposition that the annual cost of coals is equal to 5 per cent. on the capital, and nearly agrees with the classes of vessels numbered 2, 3, and 5 in the former Table VIII.

This proportionate cost of coals is here applied to cases in which the cost of the engine-power, (exclusive of boilers, wheels or screw,) is equal to 15 per cent. of the capital, say as in Classes 3 and 5, and also to cases in which the cost of the engine-power is 20 per cent. of the capital, as in Class 2. Column A gives the proportionate size or nominal horse-power of engines; column B the proportionate quantity of coal required to develope an equal amount of power (in each case); column C the proportionate cost of coal in per-centage of capital; column D the proportionate saving in cost of coal in per-centage of capital, from which it appears that if the size of the Engines be doubled, the saving is 1·45 per cent. on the capital, and if the size of the Engines be increased to 3 times, the saving is 2·15 per cent. on the capital. From this saving on the item of coal, however, must be deducted the interest on the extra cost of larger engines, and this deduction will vary according to the proportionate expenses of the engines to the capital. Columns E, F, G apply to the case in which the cost of the Engines alone (exclusive of boilers, wheels or screw) amounts to 15 per cent. of capital, (as in American vessels, and the Eastern Steam Navigation

Company;) and columns H, I, J to the case in which the cost of Engines alone amounts to 20 per cent. of capital, as in Continental Steamers, &c.; columns E and H give the necessary per-centage of increase of capital; columns F and I the permanent charge on capital, being 5 per cent. allowed on the necessary addition made to it; and columns G and J the gross gain in per-centage of capital, after deducting the interest on extra cost of Engines from the total gain or saving in coal. These results show that if the size of the Engines be doubled an additional 0·70 or 0·45 per cent. may be paid on capital, and that upon the Engines being increased to 3 times the size, an additional 0·65 or 0·15 per cent. may be paid on capital, according as the cost of the engine-power amounts to 15 per cent. or 20 per cent. of the capital respectively.

The second Table, XIII., is constructed in the same manner as the first, the annual cost of Coals being taken at 15 per cent. of the capital, which, as before-mentioned, applies to the class of vessels marked 1, and the West India Mail boats. This annual cost of Coals is applied to the cases in which the cost of engines, (exclusive of boilers, wheels, or screw,) amounts to 20 per cent. of the capital, and also to the cases in which the cost of engines alone amounts to 30 per cent. of the capital; the general results are, that if the engines be increased to double the size, for the sake of expansive working, the saving of coal would be 4·35 per cent. of capital, and if the engines be increased to 3 times the size, the saving in coal would be 6·45 per cent. of capital. These amounts are reduced by the extra cost of engines respectively to 3·35 per cent., and 2·85 per cent. of capital, and to 4·45 per cent., and 3·45 per cent. of capital, according as the cost of engine-power amounts to 20 per cent. or 30 per cent. of capital.

TABLE XII.

Table showing the Increased Dividend on Capital, by a Saving in Coal from Expansive Working; the extra Cost of larger Engines being taken into account; Boilers, Wheels or Screw, and Indicated Horse-Power being supposed to remain the same.

Proportional Nominal Horse-Power, or Size of Engines.	Proportional Cost of Coal for same actual Power.	ANNUAL COST OF COALS TAKEN AT FIVE PER CENT. OF CAPITAL.							
				Cost of Engines alone (exclusive of Boilers, Screw, &c.,) equal to 15 per cent. of Capital (say as in Classes 3 and 5).			Cost of Engines alone (exclusive of Boilers, Screw, &c.,) equal to 20 per cent. of Capital (say as in Class 2).		
		Cost of Coal in per-centage of original Capital.	Saving in Cost of Coal in per-centage of original Capital.	Increasing the Nominal Horse-Power, adds to Capital Invested.	Permanent charge on Capital, being 5 per cent. on Addition.	Gross gain on Capital, deducting amounts in F from D.	Increasing the Nominal Horse-Power, adds to Capital Invested.	Permanent charge on Capital, being 5 per cent. on Addition.	Gross gain on Capital, deducting amounts in I from D.
		Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
1	1·00	5·00	...	...	...	...	...	...	...
$1\frac{1}{2}$	·81	4·05	·95	7·50	·37	·57	10·00	·50	·45
2	·71	3·55	1·45	15·00	·75	·70	20·00	1·00	·45
$2\frac{1}{2}$	·63	3·15	1·85	22·50	1·12	·72	30·00	1·50	·35
3	·57	2·85	2·15	30·00	1·50	·65	40·00	2·00	·15
A	B	C	D	E	F	G	H	I	J

TABLE XIII.

Table showing the Increased Dividend by a saving in Coal from expansive working, the extra cost of larger engines being taken into account, (boilers, wheels or screw, and indicated Horse-power being supposed to remain the same.)

Proportional Nominal Horse-power or size of Engines.	Proportional cost of coal for same actual power.	ANNUAL COST OF COALS TAKEN AT 15 PER CENT. OF CAPITAL.							
				Cost of Engines alone, (exclusive of boilers, screw, &c.,) equals 20 per cent. of Capital. (as in West India Mail Boats.)			Cost of Engines alone, (exclusive of boilers, screw, &c.,) equals 30 per cent. of Capital. (as in River Boats, Class 1.)		
		Cost of Coal in per-centage of original Capital.	Saving in cost of Coal in per-centage of original Capital.	Increasing the Nominal Horse-power, adds to Capital invested.	Permanent charge on Capital, being 5 per cent. on addition.	Gross gain on Capital, deducting amounts in F from D.	Increasing the Nominal Horse-power, adds to Capital invested.	Permanent charge on Capital, being 5 per cent. on addition.	Gross gain on Capital deducting amounts in I from D.
		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
1	1·00	15·00	—	—	—	—	—	—	—
1½	·81	12·15	2·85	10	·50	2·35	15	·75	2·10
2	·71	10·65	4·35	20	1·00	3·35	30	1·50	2·85
2½	·63	9·45	5·55	30	1·50	4·05	45	2·25	3·30
3	·57	8·55	6·45	40	2·00	4·45	60	3·00	3·45
A	B	C	D	E	F	G	H	I	J

TABLE XIV.

Table showing the Increased Dividend by a saving in Coal from Expansive Working, the extra Cost of Larger Engines being taken into account (Boilers, Wheels or Screw, and indicated Horse-power, being supposed to remain the same).

Proportional nominal Horse Power, or size of Engines.	Proportional Cost of Coal for same actual Power.	ANNUAL COST OF COALS TAKEN AT 25 PER CENT. OF CAPITAL.				
		Cost of Coal in per-centage of original Capital.	Saving in Cost of Coal in per-centage of original Capital.	Cost of Engines alone (exclusive of Boilers, Screw, &c.), equal to 15 per cent. of Capital. (as in Australian Vessels, Class 4.) Increasing the Nominal Horse Power adds to Capital Invested	Permanent Charge on Capital, being 5 per cent. on addition	Gross gain on Capital, deducting the amounts in F from D.
		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
1	1·00	25·00	..	..	..	..
1½	·81	20·25	4·75	7·50	·37	4·38
2	·71	17 75	7·25	15·00	·75	6·50
2½	·63	15·75	9·25	22·50	1·12	8·13
3	·57	14·25	10·75	30·00	1·50	9·25
A	B	C	D	E	F	G

The third Table, XIV., is constructed in the same manner as the two former ones, the annual cost of Coals being taken at 25 per cent. of the capital, which, as shown before, applies to the Australian vessels, or class 4, where the cost of engines alone, (exclusive of boilers, wheels, or screw,) is equal to about 15 per cent. of capital. The results are, that if the size of the engines be doubled for expansive working, the saving of Coal would amount to 7·25 per cent. of capital, and if increased to 3 times the size, the saving of Coal would amount to 10·75 per cent. of capital. These amounts are reduced by the extra cost of engines to 6·50 per cent. and 9·25 per cent. of capital.

It is evident that the dearer the coal is, or the larger the quantity consumed in proportion to the actual power developed, the more advantageous would be the saving effected by expansive working, as the per-centage of saving in coal would the sooner cover any extra cost of engines; and the foregoing tables clearly show that if the size of the

engines be increased to *three* times for expansive working, and their *cost* be consequently *doubled*, there yet remains a gain under the worst circumstances, of ·15 per cent. on capital, and under favourable circumstances, such as those presented by the Australian vessels, of 9½ per cent. on capital.*

It is proposed now to consider the effect of increasing the size of the Engines for expansive working, as regards the *total weights* carried; and the following Table XV., gives the relative increase of weight resulting from an ordinary engine being increased in size from 1 to 1½, 2, 2½, and 3 times; also the proportionate quantity of coal consumed in a given time; the saving in weight of coal balancing the increase in weight of engines, where the proportion of coal is large. The two last columns give the ratios of time, and the proportionate number of days the coal would last in the respective cases, if the gross weights carried were kept the same.

The general results may be given as follows;—that when the size of the Engines is doubled, the gross weights of machinery and coal together are

						Increase.	
Increased	in Class 1, from	1·25	to	1·68	equal to	34	per cent.
,,	in Class 2, from	2·00	to	2·21	equal to	10½	,,
,,	in Class 3, from	2·50	to	2·56	equal to	2½	,,
and are						Decrease.	
Decreased	in Class 4, from	5·00	to	4·34	equal to	13	per cent.
,,	in Class 5, from	8·00	to	6·47	equal to	19	,,

Also when the size of the Engines is increased to 3 times, the gross weights of machinery and coal together are

						Increase.	
Increased	in Class 1, from	1·25	to	2·14	equal to	71	per cent.
,,	in Class 2, from	2·00	to	2·57	equal to	28½	,,
,,	in Class 3, from	2·50	to	2·85	equal to	14	,,
and are						Decrease.	
Decreased	in Class 4, from	5·00	to	4·28	equal to	14	per cent.
,,	in Class 5, from	8·00	to	5·99	equal to	25	,,

* It has not been considered necessary to include more than the 5 classes of vessels in the foregoing Tables, although many other classes exist, in which the proportionate cost of coal and machinery vary from the amounts given. In order, however, to ascertain what advantages would be gained by the substitution of larger engines in any specific case, it will only be necessary to substitute the correct amounts in place of those given above.

TABLE XV.

Table showing the proportionate Weights of Machinery and Coal, and Joint Weights of same, when the Size or nominal Horse-Power of Engines is varied, (indicated Horse-Power supposed the same in all cases respectively.)

Class.	Service.	Ratios of Nominal Horse-Power.	* Ratios of weight of machinery correspond'g to increase of nominal H.P.	Ratios of weight of coal correspond'g to increase of nominal horse-power	Ratios of total weights.	Ratios of time the coal would last if the total wts. be kept the same.	Ratio in Days.
1	River.	1	1·00	·25	1·25	1	2½
		1½	1·25	·20	1·45	—	—
		2	1·50	·18	1·68	—	—
		2½	1·75	·16	1·91	—	—
		3	2·00	·14	2·14	—	—
2	Coasting and Continental.	1	1·00	1·00	2·00	1·00	10
		1½	1·25	·81	2·06	·92	9
		2	1·50	·71	2·21	·70	7
		2½	1·75	·63	2·38	·39	4
		3	2·00	·57	2·57	·00	0
3	Ocean (Short voyages) and government.	1	1·00	1·50	2·50	1·00	15
		1½	1·25	1·21	2·46	1·03	15½
		2	1·50	1·06	2·56	·94	14
		2½	1·75	·94	2·69	·80	12
		3	2·00	·85	2·85	·59	9
4	Ocean (Long voyages) Australian.	1	1·00	4·00	5·00	1·00	40
		1½	1·25	3·24	4·49	1·15	46
		2	1·50	2·84	4·34	1·23	49
		2½	1·75	2·52	4·27	1·29	51½
		3	2·00	2·28	4·28	1·31	52½
5	Ocean (voyages out and home), Eastern Steam Navigation Company.	1	1·00	7·00	8·00	1·00	70
		1½	1·25	5·67	6·92	1·19	83
		2	1·50	4·97	6·47	1·30	91
		2½	1·75	4·41	6·16	1·41	99
		3	2·00	3·99	5·99	1·50	105

* The boilers, water, wheels or screw, are supposed the same, and the engines alone equal to half the gross weight of machinery.

The last columns show that in the 4th Class, where the weight of coal carried is equal to 4 times the gross weight of machinery, if the size of the Engines be doubled, the same gross weight being taken, then the coals will last 9 days longer—equal to 22 per cent. increase, and if the size of the Engines be increased to 3 times, and the gross weight carried be kept the same—then the coal will last 12½ days longer—equal to 31 per cent. increase.

Also in the 5th Class, where the weight of coal carried is equal to 7 times the gross weight of machinery, if the size of the Engines be doubled, the gross weight being kept the same, then the coal will last 21 days longer—equal to 30 per cent. increase; and if the size of the Engines be increased to 3 times, and the gross weight carried be kept the same, then the coal will last 35 days longer—equal to 50 per cent. increase.

The last part of the subject to be now considered, is the effect which the increase in the size of the Engines has upon the *total spaces* occupied by machinery and coals together. Table XVI. gives the results, where the size increases from 1 to 1½, 2, 2½, and 3 times, for the three divisions into which the 5 Classes of vessels, before spoken of, are reduced.

In Class 1 the coals occupy a space *equal* to that occupied by the engines alone; in Classes 2 and 3, *three times;* and in Classes 4 and 5, *five times* the space occupied by the engines alone.

The space above spoken of is horizontal space, taken at the greatest beam of the vessels.

The general results are, that if the size of the Engines be doubled, then the total space occupied by Machinery and Coals taken together (the Coals lasting the same time in all cases)—

In Class 1, . increases from 4·00 to 4·21, equal to 5 per cent.
In Classes 2 and 3, decreases from 6·00 to 5·63, equal to 6 „
In Classes 4 and 5, decreases from 8·00 to 7·05, equal to 12 „

Also, if the size of the Engines be increased 3 times, then the total space occupied by Machinery and Coals taken together—

In Class 1, . increases from 4·00 to 4·57, equal to 14 per cent.
In Classes 2 and 3, decreases from 6·00 to 5·71, equal to 5 „
In Classes 4 and 5, decreases from 8·00 to 6·85, equal to 15 „

TABLE XVI.

Table showing the Relative Spaces occupied by Engines, Boilers, and Passages, and Coals, separately and together; the size or nominal Horse-power increasing from 1 *to* 3 *; the actual or indicated horse-power remaining the same.*

Class.	Service.	Ratios of Size or nominal Horse-power.	Ratios of Spaces occupied by Engines alone. *	Spaces occupied by Boilers and Passages (Constant). **	Ratios of Spaces occupied by Coals. ***	Ratios of Total Spaces.
1	River.	1	1·00	2	1·00	4·00
		1½	1·25	2	·81	4·06
		2	1·50	2	·71	4·21
		2½	1·75	2	·63	4 38
		3	2·00	2	·57	4·57
2 and 3	Coasting and Continental and Ocean (Short Voyages.)	1	1·00	2	3·00	6 00
		1½	1·25	2	2·43	5·68
		2	1·50	2	2·13	5·63
		2½	1·75	2	1·89	5·64
		3	2·00	2	1·71	5·71
4 and 5	Ocean (Long Voyages) and Eastern Steam Navigation Co.'s Vessels.	1	1·00	2	5·00	8·00
		1½	1·25	2	4·05	7·30
		2	1 50	2	3·55	7·05
		2½	1·75	2	3·15	6·90
		3	2 00	2	2·85	6·85

Table XVII. shows how the *cargo space* is diminished or increased under the three suppositions, that the Machinery and Coal space is *equal* to the cargo space, or to *two-thirds*, or to *one-half* the cargo space; these proportions embracing the ordinary limits.

* The actual horizontal space occupied by Engines may be taken generally at 3/4 square foot per nominal horse-power.

** The actual space occupied by Boilers may be taken at 1 square foot per nominal horse-power, and Passages at 1/2 square foot.

*** The space occupied by the Coals varies,—Class 1, 3/4 square foot; Classes 2 and 3, 2¼ square feet; and Classes 4 and 5, 3¾ square feet per nominal horse-power.

Ratios—Engines, 1; Boilers and Passages, 2; Coals, 1, 3, and 5 respectively.

TABLE XVII.

Table showing the per-centage of loss or gain in Cargo Space, and the per-centage of Saving in quantity of Coals required, when the size or nominal horse-power of the Engines is increased, the indicated horse-power being the same.

Ratios of Total Spaces occupied by Machinery and Coals (from foregoing Table).	The same Ratios, but showing the per-centage of increase or decrease.	PER-CENTAGES in which the CARGO SPACE is diminished or increased. 1st. When the total Machinery and Coal space is *equal* to the total Cargo Space.	2nd. When the total Machinery and Coal space is 2/3 of the total Cargo Space.	3rd. When the total Machinery and Coal space is 1/2 of the total Cargo Space.	Ratios of Coals consumed in the same time, and developing the same power.	Per-centage of Coal saved by Expansive working.
						per cent.
4·00	100	diminishes per cent.	diminishes per cent.	diminishes per cent.	100	—
4·06	101⅓	1½	1	¾	81	19
4·21	105	5	3⅓	2½	71	29
4·38	109	9	6	4½	63	37
4·57	114	14	9⅓	7	57	43
						per cent.
6·00	100	increases per cent.	increases per cent.	increases per cent.	100	—
5·68	94	6	4	3	81	19
5·63	94	6	4	3	71	29
5·64	94	6	4	3	63	37
5·71	95	5	3⅓	2½	57	43
						per cent.
8·00	100	increases per cent.	increases per cent.	increases per cent.	100	—
7·30	91	9	6	4½	81	19
7·05	88	12	8	6	71	29
6·90	86	14	9⅓	7	63	37
6·85	85	15	10	7½	57	43

If the engines be doubled in size, then

In Class 1, the cargo space diminishes 5, 3⅓ and 2½ per cent.
In Classes 2 and 3, ,, ,, increases 6, 4 and 3 ,,
In Classes 4 and 5, ,, ,, increases 12, 8 and 6 ,,

If the engines be increased in size 3 times, then

In Class 1, the cargo space diminishes 14, 9½, and 7 per cent.
In Classes 2 and 3, „ „ increases 5, 3½, and 2½ „
In Classes 4 and 5, „ „ increases 15, 10, and 7½ „
The last column gives the per-centage of saving in coal.

The effects of *increasing the size* or nominal horse-power of engines, for the purpose of working the steam more expansively have now been considered, in respect both to the *increased first cost of machinery*, so far at least as the interest on the increased capital is concerned, the *saving of coal* in per centage of capital, the *increase of weight of machinery*, and the *saving in weight of coal*, and also in respect to the *total spaces occupied by machinery and coal*, as also the effect of the changes on the *cargo space* in per centage of the first supposed cargo space; and it is considered that the results are such as are not generally known, and that merchants and ship-owners are wholly unaware of the advantages of working steam expansively, even should they be compelled at the outset to pay double the amount now usually paid for engine power.

It would appear certain that if no alternative existed but that of increasing, say the diameter of the cylinders of marine engines, and thus increasing the first cost in about the proportion of 1½ times for double the size, and 2 times for 3 times the size (the boilers, wheels, or screw being supposed to remain the same), ample reason still exists for making such a change in contracting for engines intended for vessels carrying a large proportion of coal; and it has been shown that if double the ordinary amount be paid for the machinery, yet 9½ per cent. increase may be paid upon the capital in some cases, after deducting for the extra cost of engines, by the economy in coal alone.

It has also been shown that notwithstanding the increased size of engines (supposed to be increased 3 times), the Australian vessels carrying a large proportion of coal, present opportunities of gaining 15 per cent. in many cases in cargo room, and further, that about 14 per cent. may be saved in the gross weights carried, taking machinery and coals together; or that so much more additional coal could be taken for a longer voyage without re-coaling.

In the foregoing tables, the size or nominal horse power of engines, has been supposed to be increased 3 times, as a limit, but no advantage has been named as resulting from the diminished cost of the boilers, since, less steam being required to develope the same power, smaller boilers would suffice. Considerable advantage, however, would follow from this reduction; or advantages might be shown, in decrease of weight and space in the boilers; but it has been considered best not to encumber the calculations with so many considerations.

The gain in cargo space is altogether an additional saving to that already named as resulting from economy in quantity of coal, but this source of profit has only been shown in a per-centage of increase of cargo space, and no money value can be set upon it, as it varies so much with the nature of the trade and freight obtained.

The following Table XVIII. presents a general summary of what has been before stated, and it will be seen from this Table, that until the quantity of coals taken in proportion to weight of machinery at least equals 1½ times, as in Class 3, or rather until it equals 2 times the gross weight of machinery, no change could be advantageously made by increasing the nominal horse-power or size of the engines; inasmuch as (on the conditions assumed) the weight of the machinery increases more rapidly than the weight of the coal diminishes.

In Classes 4 and 5, however, an *increase in the weight of the engines* is soon covered by the *reduction in weight of coal* required.

The increase in the weight of engines would be found to be about balanced by the decrease in weight of coal required, if the quantity of coal taken was equal to double the gross weight of machinery; the boilers being supposed to remain the same. In these calculations it must be remembered, that the boilers are supposed to remain the same, and the weight of the engines alone, are supposed to increase in the ratio of 1½ times the weight for double the size or nominal horse-power, and 2 times the weight for 3 times the size or nominal horse-power.

TABLE XVIII.—GENERAL SUMMARY.

Table compiled from the foregoing Tables, the size or nominal horse-power increasing from 1 to 2 and 3 times (the intermediate sizes being omitted), and based on the supposition that in order to work expansively, the Engines must be increased in cost, weight, and size, the boilers being assumed to remain the same. The steam pressure supposed at only about 20 lbs. above the atmosphere.

Class	Service.	Ratio of size or nominal horse power.	Saving in coal in percentage of capital.	Increase of capital per cent.	Total weights of coal and machinery—increase or decrease per cent.	Total spaces occupied by coal and machinery—increase or decrease per cent.	Cargo Space, decrease or increase, per cent.			Per centage of increase of time the coals would last, if the total weights be kept the same.	No. of days the coals will last, if total weights be kept the same.
							When total machinery and coal space is *equal* to cargo space.	When total machinery and coal space is ⅔ of cargo space.	When total machinery and coal space is ½ of cargo space.		
			Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Days.
1	River . . .	1	—	—	Increases.	Increases.	Decreases	Decreases	Decreases	—	2½
		2	4·35	30	34	5	5	3⅓	2½	—	—
		3	6·45	60	71	14	14	9⅓	7	—	—
2	Continental .	1	—	—	Increases.	Decreases.	Increases	Increases	Increases	—	10
		2	1·45	20	10½	6	6	4	3	—	—
		3	2·15	40	28½	5	5	3⅓	2½	—	—
3	Ocean—Short voyage . .	1	—	—	Increases.	Decreases.	Increases	Increases	Increases	—	15
		2	1·45	15	2½	6	6	4	3	—	—
		3	2·15	30	14	5	5	3⅓	2½	—	—
4	Ocean—Long voyage . .	1	—	—	Decreases.	Decreases.	Increases	Increases	Increases	—	40
		2	7·25	15	13	12	12	8	6	22	49
		3	10·75	30	14	15	15	10	7½	31	52½
5	Ocean—voyage out and home	1	—	—	Decreases.	Decreases.	Increases	Increases	Increases	—	70
		2	1·45	15	19	12	12	8	6	30	91
		3	2·15	30	25	15	15	10	7½	50	105

The importance of the gain in cargo-space, may be thus estimated, taking the Australian vessels as an instance) :—

Supposed capital of company	£100	0	0
Working expenses supposed at 65 per cent, with the coals 25 per cent.	65	0	0
To pay 5 per cent. the receipts must be	70	0	0

With engines increased to 3 times size—

The capital increased to	£130	0	0
Working expenses reduced by saving of 43 per cent. off coals at 25 per cent.	54	5	0
To pay 5 per cent the receipts need only be (£54 5 0 × £6 10 0)	60	15	0

But the receipts on former supposition are £70, showing an addition of 7 per cent. on the increased capital, or 9¼ per cent. on the original supposed capital.

To this add from 7½ to 15, say 10 per cent. on receipts, extra cargo space, equal to £7.

This gives total receipts	£77	0	0
Working expenses	54	5	0
Balance for dividend	£22	15	0

This on £130 equals 17½ per cent.

It can be shown also that with *improved machinery*, comparatively no extra capital would be needed, and that no additional space would be required in engine room, so that a *saving of* 43 *per cent.* in coal would give 10¾ per cent. on capital in the case of Australian vessels, and add besides from 13½ per cent. to 27 per cent.,—say 18 per cent. to the cargo space, and consequently to the receipts—

Thus capital	£100	0	0
Working expenses reduced to	54	5	0
Receipts as before, £70, to which add 18 per cent. =£12 12 0 for extra cargo-space, making total receipts	82	12	0
Leaving for dividend	£28	7	0

In the foregoing paper the object of the Author has been merely

to collect a few particulars of the different classes of vessels, and to give a rough approximation to the effects which would be produced by a certain saving in fuel, even did no alternative exist but that of increasing the size and weight of the engines.

There does not appear to be much doubt about a *saving in fuel*, even of 40 *per cent.* being made by *expansive working*, considering what is now the general average consumption.

If the present ordinary consumption be taken at 4½ lbs. of coal per indicated horse-power, a saving of 40 per cent. would reduce it to 2¾ lbs. per horse-power, and this quantity will appear ample, when it is considered that many land engines are working with 2½ lbs. per indicated horse-power.

The pressure of steam assumed in the foregoing calculations of the saving of coal, where different sized engines are employed, has been only 20 lbs. above the atmosphere. A very much larger saving would however result, if steam of a higher pressure were used. The principle upon which the engines are supposed to be altered, is that of increasing the diameter of an ordinary cylinder, presuming the stroke to remain the same.

As the interests of Marine Engineers and Steam Ship Builders must, in the long run, be identical with those of the merchants or companies employing them, it is clearly of the utmost importance to endeavour by every means to economize fuel. Little, however, can be hoped for so long as the merchant determinately refuses to pay for that economy in some shape or other. It is not to be expected that engineers will supply larger engines than custom necessitates, and for which they obtain no additional payment; nor will they exercise their talents to economize in that direction which appears least appreciated.

Considerable competition has for a long time existed amongst engineers for the purpose of reducing the space occupied by engines, but this has been done without reference to the question of economy in total space of machinery and coal, or without reference to economy in consumption of fuel.

This competition has been, nevertheless, productive of much good, as reduction in weight and space occupied by engines is of the utmost importance, other things remaining the same.

It is believed, however, that when the subject is better understood by merchants than it appears to be at the present time, they will no longer refuse to purchase the economy when offered to them.

Were the Government now to throw open a contract, where *economy in fuel* was the object sought, in the same manner as they did some years ago, when *economy in space and weight* were the objects, we might look for the same or greater benefits than then resulted from so advisable a plan.

The author has now to show in what manner he believes nearly all the advantages enumerated in the foregoing Tables can be obtained, by a peculiarly constructed Engine of his invention, adapted for the *expansive use of steam*, without those disadvantages which have doubtless prevented the more general adoption of the principle of expansion in Marine Engines, *viz.*, the increased size, weight, and cost of the Engines.

The degree of expansion to which it is necessary to work, in order to obtain great economy, would seem to require an arrangement of Engine different from the ordinary one; inasmuch as the great variation of pressure from the beginning to the end of the stroke would cause considerable irregularity in the working of an engine where no fly wheel can be employed. Added to this objection, there is also another of equal importance—the necessity of making all parts of the engine, (where a single cylinder of large capacity is used for expansive working,) strong enough to resist the greatest strain to which they are subject, namely, that at the commencement of the stroke; the weight and cost of engine rising also in a corresponding degree with its strength. In order, therefore, to overcome these objections, and adapt it for marine purposes, it seems necessary that an engine should be arranged on the following principles:—

1st. That the steam on its first entrance should act upon a comparatively small area.

2nd. That it should finally expand to a considerable extent, the limit being determined by the friction of the machinery and the pressure of uncondensed vapour in the condenser.

3rd. That the variation in total pressure from the beginning to the end of the stroke should be as small as possible for any given expansion.

4th. That the work done by the in and out strokes, (*i. e.*, of a horizontal screw engine,) should be equal, or as nearly so as possible.

5th. That the horizontal or floor space occupied should be as small as possible—the height not being of great importance if within, say 6 or 8 feet.

6th. That the strain upon all parts of the engine should be as nearly uniform as possible, and not concentrated at any portion of the stroke.

7th. That the steam from its entrance to its exit should work against a vacuum if possible.

The arrangements shown in Plates 15, 16, and 17, meet to a considerable extent the above conditions. They are all upon the *double* expansive principle, and therefore may be said to work with both high and low pressure steam.

Figs. 1 and 2, Plates 15 and 16, show an arrangement in which the high pressure steam enters in the upper part of the cylinder, and presses upon the *annular* space AA round the trunk—this being comparatively a small surface—it is cut off at $\frac{1}{4}$ or $\frac{1}{3}$ of the stroke, according to circumstances, and then is passed to the lower end B of the cylinder, in which it is expanded to the extent required—this being in the ratio of the annular space to the whole area of cylinder. During the time the high pressure steam is acting on the annular space AA, the lower part B of the same cylinder is open to the condenser C, and while the steam is expanding in the lower part of the cylinder, on an are a equal to that of the trunk D, a vacuum is maintained in the bottom of the *opposite* cylinder F, and so admits of the greatest degree of expansion. The trunks D, E of the two opposite cylinders being firmly connected together by the rods HH, causes the pistons of both cylinders to move simultaneously, and the gross power exerted in each direction is made up of the pressure of the high-pressure steam in one cylinder, and the expanding steam in the other or opposite cylinder. The trunks are for the purpose of shortening up the engines as much as possible.

The main features in this arrangement are first, that the atmospheric pressure on the outer end of the trunk is counterbalanced, which if not done would prevent the steam being worked so expansively, as the pressure of the atmosphere on the trunk would be added to the pressure of the high-pressure steam which is not required, and would have to be balanced by the expanding steam, which (in order to maintain an effective moving power) could not then be expanded to the same extent; and secondly, that the high pressure steam acts only upon a comparatively small area.

Fig. 3, Plate 17, shows an arrangement, by which an objection to a large trunk could be overcome. This plan is much the same as Sims' arrangement, only having a trunk D attached to the pistons for economizing space, a vacuum is here maintained *constantly* in the space GG between the two pistons; the high-pressure steam acting on the bottom of the small piston at A, and afterwards expanding in the annular space BB. The trunks D E being small in this case, the same necessity would not exist for combining opposite trunks together, though in the event of the power being large and 4 cylinders employed, an evident advantage would follow.

Fig 4, Plate 17, shows an arrangement by which an engine, on the above plan, could be made double-acting, that is, having high-pressure steam admitted on *both* sides of the small piston at A and EE alternately, and using *both* sides of the large piston BB and GG alternately for expansion. This is done in the way shown—the cylinders being distinct, and the trunk D being encased as it were by a tube through the large cylinder—thus avoiding any internal stuffing-box. In this arrangement the large piston is an *annular* one, and the junction between the two pistons is made *externally* by two or more piston-rods FF being attached to the large piston and to the trunk.

There are several other forms in which the same principles may be carried out.

In Fig. 1, where only two cylinders are required, the atmospheric pressure on the trunk may be counterbalanced by an opposite *piston* or *trunk* working in a fixed cylinder or condenser having a vacuum maintained in it.

The modifications would all depend upon the particular objects sought, and the conditions to be fulfilled in each case.

The CHAIRMAN observed that the subject of the further development of the expansive principle, in the different forms of steam-engines, had become one of great practical importance, and had been at present only very partially carried out; they were most probably only on the threshold of extensive improvements in the steam-engine, and particularly in the application of the expansive principle, combined with higher pressures than had been hitherto generally used. The degree of expansion of the steam was seldom carried at present beyond about three times, but he thought it might be carried up before long to ten times, or even higher, the important economy of which had been so ably shown in the paper read by Mr. Allen. To carry this out thoroughly, so as to obtain the full commercial benefit of the economy that was practicable, a considerably higher pressure of steam in the boilers would be requisite than was at present generally made use of; the pressure in the marine and land condensing engines had been already increased very generally from the old limit of 6 or 7 lbs. above the atmosphere, to about 20 lbs. per square inch; and in the Cornish engines to 40 or 45 lbs.; but it did not appear impossible that this might be ultimately increased even to 100 or 120 lbs., as was constantly used in locomotive engines.

Mr. ALLEN said, that in the calculations in his paper, he had assumed an increase of pressure over the present general practice, but to be within safe limits in reference to the present construction of marine boilers, he had not taken a higher pressure than 20 lbs. as the basis of his calculations. A considerably higher proportion of economy would, however, be obtained, if higher pressures were made practicable by employing boilers constructed on different principles from those ordinarily used for condensing engines.

Mr. WILLS remarked, that there appeared to him an omission in

one part of the argument as stated in the paper, in not calculating a provision for paying back the excess of capital required for furnishing the larger sized engines proposed to be introduced, to allow of the expansion being carried out to the additional extent proposed. The interest for this extra capital had been included in the calculation, but he thought in order to make a complete commercial comparison, an additional annual amount should be set apart for paying off the extra capital itself, within the period of the lifetime of the engines, as their durability could not be considered as increased by their being enlarged. He thought this consideration might partly account for the want of attention on the part of steam-boat companies to the application of the principle of expansion.

Mr. Allen said that item had not been taken into account in the calculation, but on the other hand, the advantage had not been taken credit for that could be obtained by the reduction practicable in the boilers from the large saving in steam, leading to a saving in first cost, and cost of repairs, as well as increase in cargo space. These advantages, he thought, would considerably outweigh the other question of original cost of engines; and in reference to their durability, he believed it was generally experienced that large engines were better to keep up than small ones, and a lower per-centage on the capital was required for the purpose.

The Chairman inquired whether any engines had been tried on the new plans that had been described in the paper?

Mr. Allen replied, that none of them had been constructed at present, as he had only recently brought out the plans.

The Chairman observed, that for employing a much higher pressure of steam, a considerable alteration in the present boilers would probably be required, in order to obtain the requisite strength; particularly in the marine boilers, in which there was at present so large an extent of flat surface. An extensive series of experiments was now making, he understood, by the Admiralty, on working steam-vessels, with increased pressures, which would probably afford important results.

Mr. Allen said, that the present limit of pressure was probably about 30 lbs. in steamers, on account of the practical difficulties

that were experienced in the construction of boilers of sufficient capacity for very large engines, and with the compactness requisite for the situation of marine boilers, and at the same time suitable for very high pressures. The principle of boiler adopted in locomotive engines, the only one in extensive practical use for such pressures, being unsuitable in the other respects.

Mr. JACKSON thought the extension of the expansive principle in steam-vessels would be an important advantage, as marine engines were undoubtedly much behind others in that respect; it would probably be carried out more extensively by private companies, as they were generally less limited in the pressure of the steam than in the Government vessels, and it would be particularly applicable to them, as their commercial success was dependant on their cargo-space, so large a proportion of which was at present lost by the room occupied by the coals requisite with the present imperfect construction of engines.

Mr. MILLER inquired whether there was any law preventing high-pressure steam being used, or limiting the pressure in steam vessels?

The CHAIRMAN said there was no legal restriction in this country; it was only on the Continent, he believed, that a limit was fixed for the pressure allowed in working boilers. In the Government steamers the boiler pressure was limited for a long time to 10lbs., but a great advance had now been made, and in the new gun-boats high-pressure non-condensing engines had been introduced working at 60lbs. per inch, which would probably be followed up by very important alterations and improvements in marine engines.

Mr. ALLEN observed that in the expenses of working steam vessels the cost of coal bore such a large proportion to the other expenses, forming the largest item of the whole, that the question of economy mainly rested on diminution in the consumption of fuel; and they could afford a considerable loss in the weight and cost of the engines, in consequence of the greater ratio of gain in the cargo-space from the reduction in the quantity of coal required, and the saving in cost of coal. The question of relative increase in cargo-space was one of great commercial importance, as the loss at present

from the large space in the vessel required for coals was very serious; a saving in capital, at the expense of cargo-space, would be a loss on the whole; whilst even at an original sacrifice of capital from the greater proportionate increase of cargo-space, a larger ratio would be gained of returns for profits. In the tables given in the paper the calculations had been made at the moderate pressure of 20 lbs. per inch, with cylinders enlarged 3 times in size, and cutting off the steam at $\frac{1}{7}$th of the stroke; with a higher pressure of steam the expansion could be carried to a greater extent, and still further economy obtained.

The CHAIRMAN observed that the subject was one of great practical importance, and the valuable and extensive calculations in Mr. Allen's paper threw great light on the commercial advantages and practicability of extending the application of the expansion principle. He suggested that the discussion be renewed at the next meeting, and hoped that Mr. Allen would be able to bring forward, on that occasion, further extended calculations, carrying out the same investigation with higher pressures of steam, from 20 lbs. up to perhaps 100 lbs. per inch. He proposed a vote of thanks to Mr. Allen for his paper, which was passed, and the discussion was adjourned.

The meeting then terminated.

After the meeting Mr. Gray, of Birmingham, exhibited several specimens of a new construction of pressure-gauge.

PROCEEDINGS.

July 25, 1855.

The General Meeting of the Members was held at the house of the Institution, Newhall Street, Birmingham, on Wednesday, 25th July, 1855; J. E. Mc Connell, Esq., Vice-President, in the Chair.

The Minutes of the last General Meeting were read by the Secretary, and were confirmed.

The Chairman announced that the Ballot-Papers had been opened by the Committee appointed for the purpose, and the following new Members were duly elected:—

MEMBERS.

John Brown, Derby.
Parkin Jeffcock, Derby.
Thomas Symes Prideaux, London.
William Stenson, Ashby-de-la-Zouch.

HONORARY MEMBER.

William Ridout Wills, Birmingham.

The following Paper, by Mr. Edward E. Allen, of London, was then read:—

ON THE COMMERCIAL ECONOMY OF WORKING STEAM EXPANSIVELY IN MARINE ENGINES.

In the paper read at the last meeting (see Proceedings Inst. M.E., April, 1855) the author endeavoured to trace out the effects which

would result from working steam more expansively than is usual in Marine Engines. These effects were considered with respect to the increased weight of the engines, and space occupied by them, and the increased capital required; and also with respect to the saving in weight and cost of coals, and increase of cargo space occasioned by a less quantity of coals being used for any given voyage.

The various calculations were based on the supposition, that the usual practice is to cut off the steam at $\frac{3}{4}$ths of the stroke; and the cylinders were supposed to be increased in capacity to $1\frac{1}{2}$, 2, $2\frac{1}{2}$, and 3 times successively, in order to effect greater expansion.

By doubling the capacity of the cylinders, it would be found that the steam must be cut off at about $\frac{1}{4}$th of the stroke; and by increasing them to 3 times, it must be cut off at about $\frac{1}{7}$th of the stroke, in order that the actual power developed may in all cases be the same, and the economy would arise simply from the steam being more expanded in the larger cylinders proposed to be substituted for those ordinarily in use. The pressure of the steam was supposed the same in each case; and the quantity of coal, presumed to be used by marine engines, was based on the supposition that steam of about 20lbs. pressure per square inch above the atmosphere was employed.

In accordance with the wish expressed at the last meeting, the author now proposes to consider the question of economy arising under different circumstances, namely, an increase in the pressure of the steam employed. There are several ways in which economy may be obtained:—1st, by working steam of the ordinary pressure more expansively than usual; this being the mode of economizing pointed out in the paper read at the last meeting: 2nd, by using steam of a higher pressure and expanding to the same extent, or in the same degree, as is now usually the case, namely, about $1\frac{1}{3}$ times, or cutting off at $\frac{3}{4}$ths of the stroke: and 3rd, by using steam of a higher pressure, and allowing it to expand much more than is now usually the case, or down to say 5 lbs. per square inch above a vacuum as a practical limit.

Thus economy would arise simply from using steam of a higher pressure, but still greater economy would result from allowing such high-pressure steam to expand fully. To render this matter clear,

it will be necessary to refer to a Table given in the paper read at the last meeting:—

Spaces occupied by Steam	1	2	3	4	5	6	7	8	9	10
Power developed	1	1·7	2·1	2·4	2·6	2·8	3·0	3·1	3·2	3·3

The quantity of steam being the same in all cases, but allowed to expand so as to occupy the increased spaces.

In this Table no allowance is made either for back pressure, or for a reduction of power owing to a reduction of temperature while expanding, which if taken into account would rather reduce the amounts given. With this exception, however, the ratios of power gained by expansion, as shown in the Table, may be considered as correct for all pressures of steam, or in other words, the same relative advantage would follow from expanding 1 cubic foot of steam into 3 cubic feet, whether the pressure were 15 lbs. or 120 lbs. on the square inch, the gain from expansion alone being in the ratio of about 2 to 1.

The high-pressure steam would however be more economical than the low-pressure, as will be seen from the following Table XIX., which gives the power developed, and the volumes of steam at various pressures formed from the same volume of water, and consequently from the combustion of the same quantity of fuel. The fourth column gives the ratios of power developed, when the steam is used *without expansion*, a back pressure of 2 lbs. being deducted. The fifth column gives the ratios of power developed when the steam is expanded down to 5 lbs. per square inch above a vacuum, and a back pressure of 2 lbs. deducted; and the sixth column gives the part of the stroke at which the steam must be cut off, so as to expand down to 5 lbs. Column 7 gives the consumption of fuel required to develop the same power, ordinary practice being taken at 100, and column 8 the per-centage saving of fuel, deduced from column 7. The last column gives the ratios of the capacity of cylinder required in each case, to develop the same power and to allow of expansion down to 5 lbs., the ratios being calculated from the size of cylinder required for 35 lbs. steam cut off at ¾ths, which is taken as 1.

TABLE XIX.

Table showing the Power developed and the Volume of Steam at different pressures, produced from the same volume of water, and consequently with the same consumption of fuel.

Total pressure (including atmosphere) in lbs. per square inch.	Volume of Water.	Volume of Steam.	Steam *not* expanded, but back pressure of 2 lbs. deducted. Ratio of power developed, compared with ordinary practice *	Steam Expanded down to 5 lbs. pressure, and back pressure of 2 lbs. deducted.				
				Ratio of power developed, compared with ordinary practice. *	Part of stroke at which steam must be cut off to expand to 5 lbs.	Consumption of fuel for the same power, in per centage of ordinary consumption.	Per centage Saving of fuel for the same power.	Capacity of cylinder required for the same power. **
						Per Cent.	Per Cent.	
15	1	1669	·66	1·24	1-2·7th	80	20	$3\frac{1}{2}$
20	1	1281	·71	1·46	1-3·5	68	32	3
25	1	1044	·74	1·64	1-4·3	61	39	$2\frac{3}{4}$
30	1	883	·76	1·78	1-5	56	44	$2\frac{1}{2}$
35	1	767	·78	1·91	1-6	52	48	$2\frac{3}{8}$
40	1	679	·80	2·02	1-6·6	49	51	$2\frac{1}{4}$
50	1	554	·82	2·22	1-8	45	55	2
60	1	470	·83	2·37	1-10	42	58	$1\frac{7}{8}$
70	1	400	·84	2·50	1-11	40	60	$1\frac{3}{4}$
80	1	353	·85	2·62	1-12·6	38	62	$1\frac{3}{4}$
90	1	316	·86	2·66	1-14	37	63	$1\frac{5}{8}$
100	1	287	·87	2·83	1-15·6	35	65	$1\frac{5}{8}$
110	1	266	·89	2·91	1-17	34	66	$1\frac{1}{2}$
120	1	250	·92	3·00	1-18	33	67	$1\frac{1}{2}$

* Ordinary practice is assumed at 35 lbs. total pressure, cut off at $\frac{5}{8}$ths of the stroke, the power developed being called 1.

** The size or capacity of cylinder in ordinary use, *i.e.*, for 35 lbs. steam cut off at $\frac{5}{8}$ths, is taken as 1.

Allowance is made in this Table for the reduction of pressure arising from a reduction of temperature during expansion, and the difference this makes may be understood by seeing from the Table that steam of 120 lbs. pressure, expanded 18 *times* only, reduces the pressure to 5 lbs. per square inch; whereas if no reduction of pressure took place from a reduction of temperature during expansion,

steam of 120 lbs. would have to be expanded 24 *times* (instead of 18 times as above) to reduce it to 5 lbs. pressure.

The Table also shows how the ordinary practice may be improved upon; for example, by using steam of 120 lbs. pressure and cutting off at 1-18th of the stroke, in which case 3 times the power will be developed from the same combustion of fuel.

As the final pressure is here supposed to be 5 lbs. in all cases, it follows that the size or capacity of cylinder required is in all cases the same, namely, about 4500 times the bulk of water evaporated. In ordinary practice, the capacity of cylinder may be taken at about 1000 times the bulk of water evaporated; so that with 120 lbs. steam, cut off at 1-18th of the stroke, although 3 times the power is obtained by the same combustion of fuel, yet the capacity of the cylinder must be about 4½ times that required for steam at 35 lbs. and cut off at ¾ths. It follows from this, that the *same* power would be developed in a cylinder 1½ times the ordinary size.

In like manner, with steam of 50 lbs. total pressure expanded to 5 lbs. (2 lbs. back pressure allowed,) the steam would require to be cut off at about ⅛th of the stroke; and in order to develop the same power as in ordinary practice, namely, 35 lbs. cut off at ¾ths, the capacity of the cylinder must be just doubled.

The amount of economy obtained by using steam at increased pressures may be found from column 5. For instance, steam at 50 lbs. pressure cut off at ⅛th gives 2·22 times the power obtained in ordinary practice, (that is, with 35 lbs. steam cut off at ¾ths); and in like manner, steam of 120 lbs. cut off at 1-18th, gives 3 times the power; so that the *same* power is obtained by the combustion of 45 and 33 per cent. of the fuel, or in other words, the saving in these cases is about 55 and 67 per cent. respectively.

In comparing this economy, due to the use of high-pressure steam, with that shown in the former paper to result from the greater expansion alone of steam of 35 lbs. total pressure, the difference is very marked; for in the latter case, increasing the size of cylinder to 1½ times, the economy was only 19 per cent., whereas with the same increase in size of cylinder and 120 lbs. steam, the saving is 67

per cent., or $3\frac{1}{2}$ times as great. Again, doubling the size of cylinder with 35 lbs. steam, the saving was 29 per cent., whereas with double the size of cylinder and 50 lbs. steam, the saving is 55 per cent., or nearly double.

It would occupy too much space to pursue the investigation so far as to exhibit at full length the economy resulting from employing steam of *increased pressure* in cylinders of the *increased sizes* assumed in the previous paper; but the cases may be considered in which the size or nominal horse-power of the engines is increased to 1, 2, and 3 times, the intermediate sizes being omitted. The comparative results are given in the following Table XX.

TABLE XX.

Table showing the relative economy of obtaining the same power by using steam of increased pressure, and by increasing the size or nominal horse-power of the engines from 1 to 2 and 3 times, (the intermediate sizes being omitted.) Back pressure allowed of $3\frac{1}{2}$lbs.

Total pressure of steam in lbs. per square inch.	Ratio of Size or Nominal Horse-power of Engines.								
	1			2			3		
	Cut off at	Final pressure in lbs. p. sq. inch.	Ratio of Coal consum.	Cut off at	Final pressure in lbs. p. sq. inch.	Ratio of Coal consum.	Cut off at	Final pressure in lbs. p. sq. inch.	Ratio of Coal consumed.
35	3-4th	$25\frac{1}{2}$	100	1-4th	$7\frac{1}{2}$	66	1-7th	$4\frac{1}{2}$	57
40	2-5	$14\frac{1}{2}$	68	1-6	$5\frac{3}{4}$	57	1-10	$3\frac{1}{2}$	51
50	1-3·3	$13\frac{1}{2}$	58	1-8	5	48	1-13	3	45
60	1-4	13	53	1-9·5	$4\frac{7}{8}$	45	1-15	3	42
70	1-5	12	48	1-12	$4\frac{3}{4}$	41	1-18	3	39
80	1-6·6	10	43	1-15	$4\frac{5}{8}$	38	...	...	...
90	1-8	$9\frac{1}{4}$	40	1-18	4	36	...	...	...
100	1-10	$8\frac{1}{4}$	38	1-22	$3\frac{3}{4}$	35	...	...	...
110	1-11	8	37	1-24	$3\frac{5}{8}$	34	...	...	...
120	1-12	$7\frac{3}{4}$	35	1-26	$3\frac{1}{2}$	32	...	...	...

From this Table it appears that a choice may frequently be made between two ways of employing steam, both resulting in the same economy, so far as the consumption of coal is concerned. For instance, steam at 50 lbs. cut off at $\frac{3}{10}$ths, and steam at 35 lbs. cut

off at $\frac{1}{7}$th, give the same results or nearly so; but the low-pressure steam requires a cylinder of 3 times the capacity of the other.

Again, steam at 70 lbs. cut off at $\frac{1}{6}$th, and steam at 50 lbs. cut off at $\frac{1}{8}$th, give the same results; but the low-pressure steam requires a cylinder of double the capacity of the other.

The results have not been carried out in the third series of columns for pressures above 70 lbs., as the final pressures fall too far below the assumed back pressure.

The consideration of the subject will now be confined to the economy that would be effected, by using steam of *increased pressure* in a cylinder of the *ordinary size.*

The following Table XXI. has been compiled in order to show with what economy steam of increased pressure can be expanded in a cylinder of the ordinary size so as to develop the same power.

The pressures begin at 35 lbs. cut off at $\frac{3}{4}$ths, which is assumed as the ordinary practice, and the power developed under these conditions is called 1. Column 1 gives the total pressures; column 2 the part of the stroke at which the steam must be cut off in each case to develop the same power; column 3 the ratio of the power developed by the same consumption of coal; column 4 the relative quantities of coal required to develop the same power; column 5 the per-centage saving of coal; and column 6 the final pressure of the steam on its exit from the cylinder.

From this Table it will be seen that in the case of an engine working with 35 lbs. steam and cutting off at $\frac{3}{4}$ths of the stroke, if it be required to increase the pressure (in order to economize) to say 70 lbs., then the steam must be cut off at about $\frac{1}{6}$th of the stroke, and the consumption of coal will be only 48 per cent. of the quantity previously consumed, the power developed remaining the same. So also if the pressure be increased to 120 lbs., the steam must be cut off at about $\frac{1}{12}$th of the stroke, and the consumption will be reduced to 35 per cent., the same power being developed. The size of the cylinder remains the same in all cases.

With respect to the weight of machinery, it will not make much difference to what pressure the steam is raised, for although the weights slightly decrease when high-pressure steam is used, yet the

difference is very little and not worth considering in the present investigation.

TABLE XXI.

Table showing the economy of working steam of increased pressure in a cylinder of the ordinary size.

Total pressure of steam in lbs. per square inch.	Part of stroke at which steam is cut off, to develop same power.	Ratio of power developed by same consumption of coal.	Ratio of coal required to develop same power.	Saving of coal in per-centage on ordinary consumption.	Final pressure of steam on leaving cylinder, in lbs. per square inch.
				Per Cent.	
35	3-4th	1·00	100	—	25½
40	2-5	1·47	68	32	14½
50	1-3·3	1·72	58	42	13½
60	1-4	1·88	53	47	13
70	1-5	2·06	48	52	12
80	1-6·6	2·28	43	57	10
90	1-8	2·44	40	60	9¼
100	1-10	2·60	38	62	8¼
110	1-11	2·70	37	63	8
120	1-12	2·80	35	65	7¾

In order to give a more complete view of the difference between the economy resulting from the increased expansion of ordinary steam, and that arising from the increase of pressure of the steam itself, the two following series of Tables, Nos. XXII. and XXIII., have been compiled.

The first series XXII., is based on the supposition that the size of the engines is increased to 1½, 2, 2½, and 3 times for expansive working, but that from improved machinery, and reduction in the weight of boilers (from diminished consumption of fuel), the gross weight of machinery and the space occupied remain constant.

The second series XXIII., is based on the supposition that the size of the engines remains constant, as well as the gross weight of machinery and the space occupied; but that the pressure increases from 35 lbs. to 60, 80, 100, and 120 lbs.

TABLE XXII.—Section A.

Table showing the Weights *of machinery and coal, and Joint Weights of same; the size or nominal horse-power increasing from* 1 *to* 3, *the indicated horse-power remaining the same.*

Class.	Service.	Ratio of size or nominal horse-power.	Gross weight of machinery constant. *	Ratio of weight of coal corresponding to increased nominal horse-power	Ratio of total weights.	Ratio of time the coal would last, if total weights be kept the same.	Ratio in days.
		1	1	·25	1·25	1·00	2½
		1½	1	·20	1·20	1·23	3
1	River	2	1	·18	1·18	1·40	3½
		2½	1	·16	1·16	1·58	4
		3	1	·14	1·14	1·75	4½
		1	1	1·00	2·00	1·00	10
		1½	1	·81	1·81	1·23	12½
2	Coasting and Continental	2	1	·71	1·71	1·40	14
		2½	1	·63	1·63	1·58	15¾
		3	1	·57	1·57	1·75	17½
		1	1	1·50	2·50	1·00	15
		1½	1	1·21	2·21	1·23	18½
3	Ocean, (short voyages,) and Government	2	1	1·06	2·06	1·40	21
		2½	1	·94	1·94	1·58	23¾
		3	1	·85	1·85	1·75	26¼
		1	1	4·00	5·00	1·00	40
		1½	1	3·24	4·24	1·23	49¼
4	Ocean, (long voyages,) Australian	2	1	2·84	3·84	1·40	56
		2½	1	2·52	3·52	1·58	63¼
		3	1	2·28	3·28	1·75	70
		1	1	7·00	8·00	1·00	70
		1½	1	5·67	6·67	1·23	86
5	Ocean, voyage out and home, Eastern Steam Navigation Company	2	1	4·97	5·97	1·40	98
		2½	1	4·41	5·41	1·58	110½
		3	1	3·99	4·99	1·75	122½

* Weight of boilers and water supposed to be reduced, and weight of engines not increased in higher ratio.

In both series of Tables, XXII. and XXIII.,

Sections A refer to the total Weights.

Sections B „ „ Spaces.

Sections C „ „ Cargo Space.

Sections D give a summary of the preceding sections.

TABLE XXII.—Section B.

Table showing the Spaces *occupied by engines, boilers, and passages together, and by coals; and also the ratio of the Total Spaces; the size or nominal horse-power increasing from* 1 *to* 3, *the indicated horse-power remaining the same.*

Class.	Service.	Ratio of size or nominal horse-power.	Space occupied by engines, boilers, and passages, constant. *	Ratio of spaces occupied by coals.	Ratio of total spaces.
1	River	1	3	1·00	4·00
		1½	3	·81	3·81
		2	3	·71	3·71
		2½	3	·63	3·63
		3	3	·57	3·57
2 and 3	Coasting and Continental, and Ocean (short voyages) ...	1	3	3·00	6·00
		1½	3	2 ·43	5·43
		2	3	2·13	5·13
		2½	3	1·89	4·89
		3	3	1·71	4·71
4 and 5	Ocean (long voyages), and voyage out and home	1	3	5·00	8·00
		1½	3	4·05	7·05
		2	3	3·55	6·55
		2½	3	3·15	6·15
		3	3	2·85	5·85

* Space occupied by boilers supposed to be reduced, and space occupied by engines not increased in higher ratio.

TABLES XXII. show the results of increased expansion of ordinary steam.

Sections A and B show how the total weights of machinery and coals taken together, and also the total spaces occupied by them, decrease from class 1 to 5, on the supposition that the gross weight of machinery and the space occupied by it remain constant.

TABLE XXII.—SECTION C.

Table showing the Gain in CARGO SPACE, *when the space occupied by the engines, boilers, and passages is constant;* the size or nominal horse-power increasing from* 1 *to* 3, *the indicated horse-power remaining the same.*

Class.	Service.	Ratio of size or nominal horse-power	Ratio of total spaces occupied by machinery and coals, from foregoing table.	The same ratio, but showing the per-centage decrease.	Per-centage Gain in Cargo Space. 1st. When total machinery and coal space is *equal* to total cargo space.	2nd. When total machinery and coal space is ⅔ of total cargo space.	3rd. When total machinery and coal space is ½ of total cargo space.
					Per Cent.	Per Cent.	Per Cent.
1	River	1	4·00	100	—	—	—
		1½	3·81	95	5	3⅓	2½
		2	3·71	93	7	4⅔	3½
		2½	3·63	91	9	6	4½
		3	3·57	89	11	7⅓	5½
2 and 3	Coasting and Continental, and Ocean (short voyages)	1	6·00	100	—	—	—
		1½	5·43	90	10	6⅔	5
		2	5·13	85	15	10	7½
		2½	4·89	81	19	12⅔	9½
		3	4·71	78	22	14⅔	11
4 and 5	Ocean (long voyages), and voyage out and home.	1	8·00	100	—	—	—
		1½	7·05	88	12	8	6
		2	6·55	82	18	12	9
		2½	6·15	77	23	15⅓	11½
		3	5·85	73	27	18	13½

* Space occupied by boilers and passages supposed to be reduced, and space occupied by engines not increased in higher ratio.

Section C shows how the cargo space continually increases from class 1 to 5.

Section D gives a general summary of the three preceding ones, and shows the per-centage of increase of time the coals would last, if the total weights of machinery and coals taken together were kept the same; and as this depends upon the saving in coal alone, the weight of machinery being supposed constant, it amounts to the same in all the classes; being equal to 40 per cent. if the engines be doubled in size, and to 75 per cent. if the engines be increased to 3 times the size.

TABLE XXII.—Section D. GENERAL SUMMARY.

Table compiled from the three foregoing Tables; the cost, weight, and space, of engines, boilers, and passages, and water, being constant; the size or nominal horse-power increasing from 1 to 2 and 3 times, (the intermediate sizes being omitted,) the indicated horse-power remaining the same.

Class	Service.	Ratio of size or nominal horse-power.	Annual saving of coal in per-centage of capital. (Table XVIII)	Increase of capital per cent.	Total weight of coal and machinery. Decrease per cent. (deduced from column 6, section A.)	Total spaces occupied by coal and machinery. Decrease per cent. (deduced from column 6, section B.)	Cargo Space—Increase per cent. 1st. When total machinery and coal space is *equal* to total cargo space.	Cargo Space—Increase per cent. 2nd. When total machinery and coal space is ⅔ of total cargo space.	Cargo Space—Increase per cent. 3rd. When total machinery and coal space is ½ of total cargo space.	Per-centage of increase of time the coals would last, if total weights be kept the same.	Number of days the coals would last, if total weights be kept the same.	Annual per-centage gain on capital from saving of coal and increase of cargo space. If the nett profits cover cost of vessel in 1 year.	Annual per-centage gain on capital from saving of coal and increase of cargo space. If the nett profits cover cost of vessel in 2 years.
			Per Cent.	Capital	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.		Per Cent.	Per Cent.
1	River	1	...	constant; cost of boilers supposed to be reduced, and cost of engines not increased in higher ratio.	...	...	...	...	...	...	2½	...	...
		2	4·35		5·60	7	7	4⅔	3½	40	3½	9·01	6·68
		3	6·45		8·80	11	11	7⅓	5½	75	4¼	13·78	10·11
2	Coasting and Continental	1	...		...	...	...	...	...	...	10	...	...
		2	1·45		14·50	15	15	10	7½	40	14	11·45	6·45
		3	2·15		21·50	22	22	14⅔	11	75	17½	16·81	9·48
3	Ocean (short voyages) and Government ...	1	...		...	...	...	...	...	...	15	...	...
		2	1·45		17·60	15	15	10	7½	40	21	11·45	6·45
		3	2·15		26·00	22	22	14⅔	11	75	26¼	16·81	9·48
4	Ocean (long voyages) Australian	1	...		...	...	...	...	...	...	40	...	...
		2	7·25		23·20	18	18	12	9	40	56	19·25	13·25
		3	10·75		34·40	27	27	18	13½	75	70	28·75	19·75
5	Ocean (voyage out and home)	1	...		...	...	...	...	...	...	70	...	...
		2	1·45		25·37	18	18	12	9	40	98	13·45	7·45
		3	2·15		37·62	27	27	18	13½	75	122½	20·15	11·15

The two last columns give the annual per-centage gain on the capital, from saving in coal and gain in cargo space; firstly, when the nett profits cover the cost of vessel in 1 year, and secondly, when the nett profits cover the cost of vessel in 2 years; the total machinery and coal space being taken at $\frac{2}{3}$ of the total cargo space in each case.

It is only on the supposition that the nett profits for a given period cover the cost of vessel or capital, that the gain from increase of cargo space can be added to the gain from saving in coal. If the vessel be supposed to have cost a sum equal to the nett profits of 3 or any other number of years, then, in order to find the total annual gain, it is only necessary to divide the annual per-centage gain from increase of cargo space by 3, or any number determined on, and add the quotient to the annual per-centage gain from saving in coal; the sum will be the gross annual per-centage gain on capital.

TABLES XXIII. show the results of increase of pressure of the steam itself.

The use of Section A may be thus illustrated: taking the 2nd class of steamers, it is seen that if steam of 35 lbs. pressure be used and cut off at $\frac{3}{4}$ths, a weight of coal equal to the weight of machinery will last 10 days; but if steam of 80 lbs. pressure be used (in the same sized cylinder), then the same power will be developed by a consumption of 43 per cent. of the fuel, the steam being cut off at $\frac{3}{20}$ths; and a weight of coal equal to the weight of machinery would last 23 days instead of 10. In like manner, if steam of 120 lbs. pressure be used (also in the same sized cylinder), then the same power will be developed by a consumption of 35 per cent. of the fuel, the steam being cut off at about $\frac{1}{12}$th; and a weight of coal equal to the weight of machinery would last 28 days instead of 10. In all the other classes of steamers the same proportions hold good.

TABLE XXIII.—Section A.

Table showing the Weights *of machinery and coal, and Joint Weights of same; the total pressure increasing from* 35 *to* 60, 80, 100, *and* 120 *lbs. per square inch; the size or nominal horse-power of the engines, the indicated horse-power, and the gross weight of machinery remaining the same.*

Class	Service.	Total pressure of steam in lbs. per square inch.	Weight of machinery supposed constant.	Ratio of weight of coal corresponding to increased pressure.	Ratio of total weights.	Ratio of time the coal would last, if total weights be kept the same.	Ratio in days.
1	River...............	35	1	·25	1·25	1·00	2½
		60	1	·132	1·132	1·88	4¾
		80	1	·109	1·109	2·32	5¾
		100	1	·095	1·095	2·63	6½
		120	1	·087	1·087	2·85	7
2	Coasting and Continental	35	1	1·00	2·00	1·00	10
		60	1	·53	1·53	1·88	19
		80	1	·43	1·43	2·32	23
		100	1	·38	1·38	2·63	26
		120	1	·35	1·35	2·85	28
3	Ocean (short voyages) and Government	35	1	1·50	2·50	1·00	15
		60	1	·795	1·795	1·88	28
		80	1	·645	1·645	2·32	35
		100	1	·570	1·570	2·63	39½
		120	1	·525	1·525	2·85	42¾
4	Ocean (long voyages) Australian	35	1	4·00	5·00	1·00	40
		60	1	2·12	3·12	1·88	75
		80	1	1·72	2·72	2·32	93
		100	1	1·52	2·52	2·63	105
		120	1	1·40	2·40	2·85	114
5	Ocean, voyage out and home, Eastern Steam Navigation Company	35	1	7·00	8·00	1·00	70
		60	1	3·71	4·71	1·88	132
		80	1	3·01	4·01	2·32	162
		100	1	2·66	3·66	2·63	184
		120	1	2·45	3·45	2·85	200

TABLE XXIII.—Section B.

Table showing the Spaces *occupied by engines, boilers, and passages together, and by coals; and also the ratio of the Total Spaces; the total pressure increasing from* 35 *to* 60, 80, 100, *and* 120 *lbs. per square inch; the size or nominal horse-power of the engines, the indicated horse-power, and the total space occupied by machinery remaining the same.*

Class.	Service.	Total pressure of steam in lbs. per square inch.	Space occupied by engines, boilers and passages, constant.	Ratio of spaces occupied by coals.	Ratio of total spaces.
1	River	35	3	1·00	4·60
		60	3	·53	3·53
		80	3	·43	3·43
		100	3	·38	3·38
		120	3	·35	3·35
2 and 3	Coasting and Continental, and Ocean (short voyages) ...	35	3	3·00	6·00
		60	3	1·59	4·59
		80	3	1·29	4·29
		100	3	1·14	4·14
		120	3	1·05	4·05
4 and 5	Ocean (long voyages) and voyage out and home	35	3	5·00	8·00
		60	3	2·65	5·65
		80	3	2·15	5·15
		100	3	1·90	4·90
		120	3	1·75	4·75

Sections A and B show how the total weights of machinery and coals taken together, and also the total spaces occupied by them, decrease from class 1 to 5, owing to a saving of coals alone. No advantage has been taken of the decrease in the space required for the boilers, although much less fuel is used; because high-pressure boilers usually occupy more space, for the same power, than low-pressure boilers.

TABLE XXIII.—Section C.

Table showing the Gain in Cargo Space, *when the space occupied by the engines, boilers, and passages is constant; the total pressure increasing from* 35 *to* 60, 80, 100, *and* 120 *lbs. per square inch; the size or nominal horse-power of the engines, and the indicated horse-power remaining the same.*

Class.	Service.	Total pressure of steam in lbs. per square inch.	Ratio of total spaces occupied by machinery and coals, from foregoing table	The same ratio, but showing the percentage decrease.	Per-centage Gain in Cargo Space. 1st. When total machinery and coal space is *equal* to total cargo space.	2nd. When total machinery and coal space is ⅔ of total cargo space.	3rd. When total machinery and coal space is ½ of total cargo space.
					Per Cent.	Per Cent.	Per Cent.
1	River	35	4·00	100	...	...	...
		60	3·53	88	12	8	6
		80	3·43	86	14	9⅓	7
		100	3·38	84	16	10⅔	8
		120	3·35	83	17	11⅓	8½
2 and 3	Coasting and Continental, and Ocean (short voyages)	35	6·00	100	...	...	...
		60	4·59	76	24	16	12
		80	4·29	71	29	19⅓	14½
		100	4·14	69	31	20⅔	15½
		120	4·05	67	33	22	16½
4 and 5	Ocean (long voyages,) and voyage out and home	35	8·00	100	...	...	...
		60	5·65	71	29	19⅓	14½
		80	5·15	64	36	24	18
		100	4·90	61	39	26	19½
		120	4·75	59	41	27⅓	20½

Section C shows how the cargo space continually increases from class 1 to 5.

The last section of Table XXIII. gives a general summary of the three preceding ones.

TABLE XXIII.—Section D. GENERAL SUMMARY.

Table compiled from the three foregoing Tables; the cost, weight, and space, of engines, boilers and passages, and water, being constant; the pressure increasing from 35 to 80, and 120 lbs. (the intermediate pressures being omitted); the size or nominal horse-power of the engines, and the indicated horse-power remaining the same.

Class.	Service.	Total pressure of steam in lbs. per square inch.	Annual saving of coal in per-centage of capital. (Table XVIII.)	Increase of capital per cent.	Total weights of coal and machinery. Decrease per cent. (deduced from column 6, Section A).	Total spaces occupied by coal and machinery. Decrease per cent. (deduced from column 6, Section B.)	Cargo Space—Increase per cent. When total machinery and coal space is *equal* to total cargo space.	Cargo Space—Increase per cent. When total machinery and coal space is ⅔ of total cargo space.	Cargo Space—Increase per cent. When total machinery and coal space is ½ of total cargo space.	Per-centage of increase of time the coals would last, if total weights be kept the same.	Number of days the coals would last, if total weights be kept the same.	Annual per-centage gain on capital from saving of coal, and increase of cargo space. If the nett profits cover cost of vessel in 1 year.	Annual per-centage gain on capital from saving of coal, and increase of cargo space. If the nett profits cover cost of vessel in 2 years.
				Capital	Per Cent.		Per Cent.	Per Cent.	Per Cent.	Per Cent.		Per Cent.	Per Cent.
1	River............	35	—		—	—	—	—	—	—	2½	—	—
		80	8·55	con-	11·00	14	14	9⅓	7	132	5¾	17·88	13·21
		120	9·75	stant;	13·00	17	17	11⅓	8½	185	7	21·08	15·41
2	Coasting and Continental	35	—	the	—	—	—	—	—	—	10	—	—
		80	2·85		28·50	29	29	19⅓	14½	132	23	22·18	12·51
		120	3·25	same	32·50	33	33	22	16½	185	28	25·25	14·25
3	Ocean (short voyages), and Government	35	—	engines	—	—	—	—	—	—	15	—	—
		80	2·85	and	34·00	29	29	19⅓	14½	132	35	22·18	12·51
		120	3·25		39·00	33	33	22	16½	185	42¾	25·25	14·25
4	Ocean (long voyages), Australian...	35	—	boilers,	—	—	—	—	—	—	40	—	—
		80	14·25	&c. being	45·60	36	36	24	18	132	93	38·25	26·25
		120	16·25	used in	52·00	41	41	27⅓	20½	185	114	43·58	29·91
5	Ocean, voyage out and home	35	—		—	—	—	—	—	—	70	—	—
		80	2·85	all	49·87	36	36	24	18	132	162	26·85	14·85
		120	3·25	cases.	56·87	41	41	27⅓	20½	185	200	30·58	16·91

It will render the results of these tables more easily understood, to trace them out with reference to one of the five classes of steamers, and as one of the most important, class 4, or the Australian Vessels, may be taken. From Table I. it will be seen that the quantity of coal usually taken is equal to about 4 times the gross weight of machinery, and that this quantity lasts about 40 days, that is, with 35 lbs. steam cut off at $\frac{3}{4}$ths of the stroke. From Table VIII. it will also be seen that the quantity of coal annually consumed if the vessels be kept at work, amounts to 25 per cent. of the cost of the vessels or capital.

Upon referring to Section D, Table XXII., it appears that if the cylinders be doubled in capacity, to allow of more expansive working, the coal required for the same time and to develop the same power is so far reduced, that $7\frac{1}{4}$ per cent. per annum is saved on the original capital; and that if the weight of coals carried be kept the same, they will last 56 days instead of 40. Also, if the cylinders be increased in capacity to 3 times, the annual saving in coal will amount to $10\frac{3}{4}$ per cent. on the original capital; and if the same weight of coals be carried, they will last 70 days instead of 40.

Referring now to Section D, Table XXIII., it appears that by using steam of 80 lbs. pressure instead of 35 lbs., the annual saving in coal will amount to $14\frac{1}{4}$ per cent. of the original capital; and that the same quantity of coals will last 93 days instead of 40. Also, if the pressure be increased to 120 lbs., the annual saving in coal will amount to $16\frac{1}{4}$ per cent. on the original capital; and the same quantity of coals will last 114 days instead of 40.

Again, if instead of carrying coals for an additional number of days, the space they would occupy be appropriated to cargo, then, by the central columns, on the supposition that the total machinery and coal space is equal to $\frac{2}{3}$rds of the total cargo space, the latter will be increased 12 and 18 per cent., when the size of the engines is increased to 2 and 3 times respectively, and 24 and $27\frac{1}{2}$ per cent., when the pressure is increased to 80 and 120 lbs. respectively. By the last columns of Section D it will be seen, that, on the same supposition, and supposing the nett profits for 2 years to be equal to the cost of the vessel, that is, the receipts on the

cargo space to be 50 per cent. of the original capital, then the total annual gain from saving in coals and increase of cargo space will be 13¼ and 19⅝ per cent. of the original capital, when the size of the engines is increased to 2 and 3 times respectively, and 26¼ and nearly 30 per cent., when the pressure is increased to 80 and 120 lbs. respectively.

These results are of the highest importance, and well deserve the consideration of those embarking capital in undertakings of this nature.

In concluding this examination of the beneficial effects of expansion, the author may remark that there are various aspects and suppositions under which they might be demonstrated, and few can be more fully aware than himself of the imperfections which may be found in these contributions to the subject. It is difficult to present a comprehensive view of the subject in an abstract form; but perhaps enough has been done to serve as a ground-work upon which calculations suited to specific cases can be based; this may be done by substituting the correct quantities in any particular case for those given in the Tables.

In the former paper the author made a deduction from the annual saving in coal for the interest on the extra capital required for larger engines of the ordinary construction; but no provision was made for the repayment of such extra capital. This might be rendered more simple by supposing the gain from saving in coals and increased cargo space to be set aside until the extra capital was repaid. This would be done in a few years, according to the ratio which the annual profits bore to the capital. After the repayment of the extra capital, the annual gain would be constant, and no reduction would have to be made for interest, the profits resulting from saving of coal and increase in cargo space.

The author will now refer to the advantages contemplated in the new forms of Engines proposed in the former paper, which are as follows:—

1st. That the steam on its entrance to the cylinder acting on a comparatively small area would admit of the pressure being con-

siderably increased, without the weight of the engine being increased to anything like the extent necessary in the case of a common cylinder of large area.

2nd. That in order to work expansively, it would not be necessary to increase the length of the cylinder or stroke of the engine, which would be the case with an ordinary engine: the double expansion rendering the length of cylinder virtually double.

3rd. That the arrangements proposed possess all the advantages of compactness obtained by the use of a trunk, thus conveniently allowing of a longer connecting rod than would be possible in any other way in the same space.

4th. That upon either of the plans represented in Plate 17, (see Proceedings, April, 1855,) the power of the engines could be almost indefinitely increased, not only by using steam of higher pressure, but also by increasing the *diameter* of the large cylinder; retaining a short stroke for the sake of getting sufficient speed for a screw engine.

5th. That the floor space required for the engines on these plans would not exceed from $\frac{1}{4}$ to $\frac{1}{3}$ of a square foot per nominal horsepower, or about half the space usually occupied by other direct-acting engines; the pressure and degree of expansion being supposed to be in both cases the same.

6th. That the space required for the engines, so as to obtain a greater degree of expansion than usual, (greater capacity of cylinder under whatever form or arrangement being of course necessary,) would not increase in a higher ratio than that in which the space occupied by the boilers would decrease, less steam being required for the same power; so that the total spaces would remain constant for almost any degree of expansion.

7th. That the steam from its entrance to its exit would work against a vacuum.

8th. That the difference of pressure at the beginning and end of the stroke would be very considerably less than in an ordinary engine, expanding to the same degree. For example: suppose an ordinary single cylinder with steam at 45 lbs. expanding 9 times, or to 5 lbs.; then, deducting the back pressure, say 3 lbs., we have

$45 - 3 = 42$ lbs. at the beginning, and $5 - 3 = 2$ lbs. at the end of the stroke, being in the ratio of 21 to 1. If the expansion take place in two stages, as in the arrangements proposed, then for the first stage we have $45 - 3 = 42$ lbs. at the beginning, and $15 - 3 = 12$ lbs. at the end of the stroke, being in the ratio of $3\frac{1}{2}$ to 1 only; and for the second stage, (taking place in the opposite cylinder,) we have $15 - 3 = 12$ lbs., and $5 - 3 = 2$ lbs., being in the ratio of 6 to 1 only. The mean total difference is only $4\frac{3}{4}$ to 1, and this for the same degree of expansion of 9 times.

9th. That the combination of the trunks not only counteracts the atmospheric pressure on the outer ends of them, which would prevent much expansion, but also saves the second connecting-rod, and further serves the purpose of guides, and prevents the work of the connecting-rod being thrown too severely on the trunk and stuffing-box. The combination of the trunks also renders the work done by the out and in strokes (of a horizontal engine) quite equal; the high-pressure steam of one cylinder always acting in conjunction with the low-pressure steam of the opposite cylinder. This equality of work in the in and out strokes cannot well be obtained with a single trunk, except it be carried through the cylinder, as in Messrs. Penn's engine. The only way in which it is ordinarily attempted is by cutting off the steam later on the trunk side of the piston, by giving the valve less lap on that side. This method of obtaining uniformity is obviously very limited, and not compatible with high degrees of expansion.

10th. That owing to the strength of the various parts of the engine being determined by the pressure of the steam on its first entrance into the cylinder, and this taking place on a comparatively small area, the cost and weight of engines would not increase as on the ordinary construction; and it is presumed that the reduction in the cost of boilérs, owing to less steam being required for the same power, would cover any extra cost of engines arising from the greater capacity of cylinder, which is required in order to work more expansively than usual.

Mr. Allen explained the drawings of his engine, and the mode of its action. He stated that his view had been principally to obtain compactness, and sufficient uniformity in the power, combined with a much higher degree of expansion than was at present used in Marine engines. There were many practical difficulties in the more extended application of the expansive principle in those engines, on account particularly of the very confined space available for them in the vessels.

The Chairman inquired whether the calculations in the paper had been made only theoretically; he supposed no actual trial of the engine upon the new arrangements proposed had yet taken place.

Mr. Allen explained that the calculations had not been made from actual indicator diagrams, as there had not been an opportunity at present of making a trial of an engine on the proposed plan; but he had made the calculations from carefully constructed diagrams, based on those obtained from the actual working of engines that were so far similar in their action, as to afford safe practical data for the calculations, and full allowance had been made for loss of temperature during expansion of the steam.

The Chairman observed that strong objections were generally entertained by marine engineers to the use of high-pressure steam for their engines; greatly on the ground, he believed, of priming, arising probably from the quantity of salt in sea water; but he did not see why these difficulties should not be surmounted.

Mr. Allen stated that in his original paper, which was read at the previous meeting, he had confined his attention to the case of low-pressure steam, 35 lbs. total pressure, or 20 lbs. above the atmosphere, as that was the general limit at present in marine engines; but in the present supplementary paper he had extended the calculations given in the previous one to the case of high-pressure steam, in accordance with the desire expressed in the former discussion.

The Chairman inquired what means he proposed, for getting over the difficulties which were met with when high-pressure steam was used.

Mr. Allen said that the object of his paper was not to investigate any special means of getting over the difficulties accompanying the use of high-pressure steam; but merely to show what advantages in point of economy would result, in case some effectual method of overcoming them could be devised.

Mr. JONES observed that facts obtained by actual trial were very essential for confirming theory on such a subject, which was one in which it would be important to have the calculations verified by practical experience; he considered that the calculations in Mr. Allen's paper threw much valuable light on the economy of expansion.

Mr. HODGE thought there would be much liability to error in basing calculations on theoretical tables only, not derived from experiments, and in adopting a new design of engine, like that brought forward in connection with the paper, which had not yet been tried in practice. He disapproved of the short stroke of the engine proposed, since the total effect with the same expansion, that is, cutting off at the same fraction of the stroke, was not so good in a short-stroke engine as in a long one; but he considered the use of the two cylinders an advantage, on account of the greater uniformity of motion thereby obtained; the latter however was not a point of such importance in the propulsion of vessels as in manufactories, since the momentum of the vessel was great, and not easily affected by irregularities in the stroke; but in driving machinery, all variations in the power given out at different portions of the stroke were detrimental. The arrangement of the trunks for shortening up the engine appeared very good, but he thought the cylinders were shorter than was advisable, because less power was obtained out of the steam by expanding the same volume of steam in a short cylinder than in a long one, as was shown by adding up the ordinates of the expansion curves.

The CHAIRMAN inquired whether the form of engines represented was expressly designed for high-pressure steam, or whether any other form would be considered preferable in that case.

Mr. ALLEN replied that the engines were not designed for very high-pressure steam, but only for pressures of about 35 to 45 lbs., including the atmosphere; the advantages contemplated in them were those arising from saving in cost and space occupied, and from allowing the expansion to be carried to a higher degree than usual; large trunks might be objectionable with very high pressure, as the effects of the difference in area would then be rendered more perceptible. The advantage of a long stroke was admitted, but it appeared to be impracticable to obtain a long stroke in a marine engine, with sufficient velocity of revolution of a screw shaft.

The CHAIRMAN inquired what was the velocity of revolution proposed with Mr. Allen's engines.

Mr. ALLEN contemplated working them up to 80 or even 100 revolutions per minute, which was about the speed required for screw shafts; this would give a speed of piston of about 300 or 400 feet per minute.

Mr. HODGE thought an engine might be driven at a considerably greater speed without difficulty; he had known 600 or 700 feet per minute attained without difficulty in a long-stroke engine, and a good indicator diagram obtained at that speed.

The CHAIRMAN remarked that, independently of the difficulty of obtaining a long stroke with a great velocity of the shaft, the section of the vessel would not generally allow of a long stroke sufficiently low down for direct-acting horizontal cylinders.

Mr. HODGE said that the balancing of the cylinders by connecting the opposite trunks appeared to him to be a new and good arrangement; he had not seen it before, and it certainly made the engine very compact; but he did not see that it was accompanied by sufficient advantages to warrant complicating the engine so much as was done by the proposed arrangement.

Mr. ALLEN explained that it was not necessary to use four cylinders, in order that the atmospheric pressure upon the open trunks might be balanced, as this could be done by working the opposite trunk in a condenser; by connecting the opposite trunks, the effects of the variation of the pressure during expansion were diminished, and the atmospheric pressure was entirely neutralised; the four cylinders were however desirable where the expansion was carried down to the extent contemplated in the paper, namely, 5 lbs. above a vacuum, as the total power exerted in both directions was thus rendered quite equal. Without the trunk the same amount of expansion could not be obtained without having engines with a long stroke.

Mr. HODGE presumed the extent of expansion was limited only by the power required to overcome the friction of the engine.

Mr. ALLEN pointed out that the steam might be expanded with advantage to this limit in the engines he had proposed, as when the most expanded steam was acting on the large area of piston, there was, in addition to this, when the trunks were coupled, the steam at its highest pressure acting on the small area in the same direction.

Mr. Hodge thought that in horizontal direct-acting engines there was often a great error in not having sufficient length of bearing in the stuffing-boxes, and also in the pistons; it was proved in practice that there was no disadvantage in a long-bearing piston if well made. He considered that long-stroke single-cylinder engines were the most economical, and were preferable wherever that form was admissible.

The Chairman remarked that considerable economy was obtainable by a greater degree of expansion, even with the present pressure; but for carrying out the principle thoroughly it was essential to obtain a considerable increase of pressure, and he thought it was very important for an advance to be made in that direction.

Mr. Allen observed that doubling the size of the cylinders gave an economy of 29 per cent. with the same pressure as that generally used, 35 to 40 lbs. per inch, which would be a very important improvement on the present working. There were several practical objections to the use of higher pressures of steam, and he was not prepared to recommend much increase at present.

Mr. Hodge inquired what objections were generally advanced to the use of higher pressures; he did not know of any really serious objection, and thought the pressure might be much increased beyond the present average with important advantage in economy of power.

Mr. Allen said the objections were mainly those arising from minor points of detail, such as priming and leakage of stuffing-boxes and boiler joints; these were practical difficulties which might very possibly be got over with further experience.

The Chairman suggested that the general objection to high-pressure steam in marine engines was to be attributed to the circumstance of those connected with them not being so much accustomed to high-pressure steam; there did not appear to be any sufficient reason why it should not be used as much in marine as in land engines, and particularly in locomotives. He thought the difficulties met with in connection with the boiler were such as ought to be got over, and would be set aside by engineers accustomed to construct high-pressure engines.

Mr. Hodge remarked that marine engineers in this country had mainly confined their attention at present to low-pressure steam; but in the large American steamers on the Hudson condensing engines were

worked with 70 lbs. steam, and a good vacuum of 28 inches was maintained without difficulty with that pressure. Of the difficulties which were urged, priming he believed often arose from the steam-pipe from the boiler being too small in diameter; he had known cases where this had been the cause. The stuffing-boxes ought to give no trouble; they were always made steam-tight with high-pressure steam by the Cornish engineers and in locomotive shops, and if not steam-tight in marine engines, the workmanship must be defective; he thought the difficulties that had been referred to were such as might be easily got over.

Mr. Allen observed that some difficulties might be treated as trivial in land engines, which became serious matters in the case of marine engines, from the difference in the circumstances; and in considering the extension of expansion in the latter class of engines, it was necessary to take account even of objections arising merely from minor points of detail. He anticipated that the first step towards improvement in marine engines would consist in using a higher degree of expansion with the present pressure of steam, and afterwards making trial of greater pressures. High-pressure steam had been very little tried yet in marine engines, and had always been found troublesome; he believed that some engines which had been originally constructed with high-pressure steam had been afterwards altered to low-pressure.

The Chairman observed that the gun-boats lately made for the Baltic fleet had steam of from 50lbs. to 60lbs. pressure, working without condensing, and he understood they answered very well, and a still higher pressure would probably be tried.

Mr. Shipton suggested that there might be some difficulty with the air-pumps shown in Mr. Allen's engine, from the speed, and the position in which they were placed.

Mr. Allen remarked that such a difficulty would not affect the principle contained in his paper; any other form of air-pump might be adopted, if desired; but he did not think any difficulty was to be anticipated in working the air-pumps even at a higher speed than he had contemplated.

The Chairman said he had recently seen engines that had worked at 130 revolutions per minute, in a vessel that had been out to Africa; the air-pumps had common leather butterfly valves, very well made, and

no difficulty had been experienced from the high speed. He remarked that the great requisite for long voyages was sufficient surface in the working bearings to prevent any tendency to heating, in order to allow the vessel to continue running several days without stopping.

Mr. SHIPTON observed that the trunks shown in Mr. Allen's engine would increase the friction considerably; he inquired whether any account had been taken of the increased friction in the calculations of the paper.

Mr. ALLEN replied that the friction was not included in the calculations, in order that they might be as general as possible, instead of being limited to a particular form of engine; but he did not think it would materially interfere with the advantages of his proposed engine.

Mr. SHIPTON observed that with the present construction of marine engines, the expansion, being performed in a single cylinder, must undoubtedly be more limited than in a compound cylinder such as had been proposed; otherwise a shock would be caused to the wheels or screw at each stroke, by the great inequalities in the driving power; and consequently, with a single cylinder, it was not advisable to cut off at a very early point in the stroke.

Mr. ALLEN said that no great degree of expansion could be obtained in marine engines, except by dividing the process into two steps as in his proposed engine, by the use of double cylinders: it would be seen, by referring to the tables, that, with, 120 lbs. steam, in order to expand down to the lowest useful pressure, in the present engines it would be necessary to cut off at 1-18th of the stroke, which was quite impracticable in a single cylinder, on account of the variation in pressure being much too great to be admissible in marine engines; it was only possible in such a case as the Cornish pumping engines, where great variation in power and velocity of piston was immaterial. But in his proposed engine this high degree of expansion could be obtained practically, by cutting off at 1-9th in the first cylinder and doubling the expansion in the second, or at 1-6th in the first cylinder and expanding three times in the second.

The CHAIRMAN inquired what degree of expansion was adopted in the large engines making at Soho for the great vessel of the Eastern Steam Navigation Company.

Mr. Garland said he believed it was not intended to work them very expansively, probably cutting off at about 1-3rd of the stroke; there were four cylinders, 84 inches diameter, with a 4-feet stroke, and intended to work with about 25 lbs. steam above the atmosphere.

The Chairman suggested that in many cases the use of 100 lbs. steam without a condenser might be practically as economical as 50 lbs. steam with a condenser, and would have the advantage in simplicity and compactness.

Mr. Allen thought that condensing was preferable in all cases, and recommended the use of 40 lbs. to 50 lbs. or 60 lbs. steam rather than a higher pressure; the steam to be expanded down to 5 lbs. He showed by a table that when the expansion was carried down to 5 lbs. above a vacuum, there was practically very little margin left for further economy, and the moving power was then very nearly counterbalanced by the friction and the back pressure of the condenser.

The Chairman remarked that their late member, Mr. W. Smith, of Dudley, had given a valuable contribution of actual results of the working of engines in the mining district, and he hoped some members would take up the subject in its different branches, to carry out the inquiry that had been so well commenced. The working results of the Cornish engines had been carefully attended to, and constant returns and comparative statements were prepared, with remarkable advantage to the owners, in the practical economy resulting from the plan; and there would doubtless be found great advantage also in the extension of the plan to other classes of engines. His own conviction was that it would be necessary in many cases of marine engines, particularly in screw steamers, to use a much higher pressure than was at present employed; the objections of engine-makers to attempting the use of high-pressure steam arose from the several practical difficulties that had then to be encountered, but he did not see any reason to doubt that these might be satisfactorily surmounted, by further endeavours and improvements in construction or arrangement. The great importance to the employers of steam power of an extension of the expansive principle, in point of economy of power and increase in the cargo space available in the vessels, had been strikingly shown in the able paper that had been read to the meeting.

He expressed a hope that the views advanced in the paper might be carried out practically, and proposed a vote of thanks to Mr. Allen for his paper and tables, which was passed.

The following Paper, by Mr. Charles Beyer, of Manchester, was then read :—

DESCRIPTION OF AN IMPROVED TUYERE AND SMITHS' HEARTH.

The present paper and accompanying drawings show the construction of a Water Tuyere, referred to by the author at a former meeting of the Institution, as having been adopted by him at his own works at Gorton, near Manchester, and found to work very satisfactorily. This construction was first proposed to him several years since, by his present foreman, Mr. John Nuttall, who designed and carried it out about fourteen years ago at Messrs Jones, Turner, and Evans' works, at Newton, Lancashire, in consequence of great difficulty having been experienced there in keeping the smiths' fires at work, from the frequent failures of the tuyeres, which were the ordinary water tuyeres. The water pipes, used in that construction of tuyere, became choked by the quantity of sediment in the water, and the nozzles were so frequently burnt out, as to cause serious delay and expense by the stoppage of the fires. Larger water pipes were tried, up to 1in. and 1¼in. bore, but without overcoming the difficulty. A cast-iron tuyere was then suggested by Mr. Nuttall, and after various modifications he arrived at the form shown in Fig. 4, Plate 19, which was found quite successful, and was gradually adopted throughout the shop, in replacing the ordinary tuyeres when worn out.

The first tuyeres were made very thick at the nozzle end, from 1¼in. to 1½in., with the view of providing for their burning away; but these were found to be liable to crack at that part, from unequal expansion, and the thickness was therefore gradually diminished,

until the casting was made of the same thickness of metal throughout, namely, about $\frac{3}{8}$in.

Figs. 1, 2, and 3, Plates 18 and 19, show an improved arrangement of Smiths' Hearth, which has been found to possess some advantages, and has been adopted by the author in the erection of his own works, in connection with the improved construction of tuyere just described.

Fig. 1 is a longitudinal section of the double hearth and tuyere.

Fig. 2 is a transverse section of the hearth, showing the tuyere in elevation.

Fig. 3 is a sectional plan of the double hearth.

The tuyere A (of which a specimen is exhibited), consists of a single casting, $\frac{3}{8}$in. thick, bolted to the front of the water-cistern B by a flange, and connected with the elbow-pipe C by a socket-joint packed with hemp; the elbow-pipe is bolted by a flange to the bottom of the cistern, and the branch-pipe D, from the air-main E, is bolted on below. An iron slide F is inserted at this joint to form the blast regulator. The flange joints are all made with a washer of soft wood, about $\frac{1}{4}$in. thick, which allows of fixing them water-tight without any fitting; and by having all the bolt-holes marked out from the same templet, any tuyere can be quickly and effectually refixed, or changed for a longer or shorter tuyere, as required, to suit any particular work, since the wood packing readily accommodates itself to any inequalities in the castings.

For simplicity and compactness of construction, the water-cistern B is made to form the back of the hearth, as shown in Figs. 1 and 3, and the blast being brought in from below, there is no loss of space between the backs of the hearths, and the two cisterns can be placed close together, back to back. This arrangement causes an important saving in shop-room, as the extreme length, from front to front, of a pair of hearths may be reduced to 12ft. The breadth of the hearths has also been reduced to 3ft. 9in. outside, which is found to be a great advantage, as it allows the smith to stand closer to his work, and enables him in many cases to lift work by hand, which, at a common hearth, would require him to use a porter-bar.

Each hearth is provided with a screen G of thin sheet-iron on the

right-hand side, which can be fixed and removed at pleasure. The chimney H, which is 15in. in diameter, is made of wrought-iron, and is lighter, less bulky, and not more expensive than a brick chimney. The chimney H and hood I, are carried by two cast-iron standards KK, which also support the water-cistern B ; these are bolted down to the bed-plate L, which forms a complete base to the hearths, and serves as a cover to the opening of the air-main E, the two branch air-pipes DD being bolted upon it by flanges. An opening M in the front of the bed-plate leads to the ashpit N. The back of the hearth above and below the water-cistern B is formed by a 4½in. brick wall between the standards KK.

By this arrangement, a simple, economical, and durable hearth is obtained, and one which allows easy access to all parts. The author erected 26 of these hearths about 10 months ago, and they have worked up to this time to his entire satisfaction ; the tuyeres and water-backs continue sound, and do not show the least appearance of failure.

A circular hollow fire, constructed for heavy wheel forging at the author's works, is shown in Figs. 5 and 6, Plate 20.

Fig. 5 is a vertical section, and Fig. 6 a sectional plan, taken through the tuyere.

This fire consists of an annular cast-iron water-cistern 4 ft, B. 6 in. outside diameter, with three tuyeres AAA fixed in it, of the same construction as that already described. Underneath the cistern is a wrought-iron air-chamber O, connected with the tuyeres by the elbow-pipes CCC, and communicating at P with the air-main E; the blast is regulated, as before, by the iron slides FFF. The water-cistern is lined with fire-brick R, which is contracted towards the top, so as to concentrate the heat; the fire-bricks being moulded can easily be renewed when required. The top of the cistern and fire-brick lining is lowered at S, to form an opening for the convenience of the workmen when heating any very heavy forging. The cinders are dropped down by means of a flap door T, into the ashpit N, from which they are removed through the trap door M.

Fig. 7 shows an enlarged section of the tuyere A.

With this fire an intense heat is obtained in the boss of the wheel

to be welded, which is placed over the opening, whilst the surrounding spokes are thoroughly protected from the action of the fire by the hearth being entirely covered in, except at the point where the heat is required. This hearth has the advantage of being small and compact, and without any projections from the circle; it thus enables the men to get close to the work all round.

A specimen was exhibited of the improved tuyere, with the wood packing.

The CHAIRMAN thought the form of hearth shown was a very good one, compact and well arranged for working, and economical in make; and the tuyere was certainly a very simple construction.

Mr. SHIPTON said he had seen the hearths at Mr. Beyer's works, and they were found to work satisfactorily; he thought it was a good arrangement.

Mr. WRIGHT considered there was an advantage in the water cistern forming the back of the fire, which was not in the other forms of hearth shown at the former meetings, and it made a very compact and convenient hearth.

Mr. SHIPTON observed that Messrs. Dunn, of Manchester, also used the water tank to form the back of the fire; and he had a hearth at his own works on the same plan, which made a very durable job.

Mr. HODGE thought the circular fire was a very good idea; he had also seen a very good circular hearth in general use in America for anthracite fires, which had a central blast entering at the bottom of the fire; this was found to have an important advantage over the ordinary plan of blowing on one side, where the iron was heated only on one side at a time, and required to be constantly turned round. He had a circular fire at work on the American plan, and was surprised they were not generally adopted in this country, as there was a great practical advantage in the plan.

Mr. SHIPTON thought there would be an advantage in the circular fire for ordinary work as well as heavy wheel work, as in the ordinary fires the time and work lost by turning the iron round in the fire, in order to heat it equally on all sides, were considerable.

Mr. CLIFT inquired whether a thicker fire was required to prevent the coals being blown up, when a vertical blast was used, as in the American anthracite fires that had been mentioned.

Mr. HODGE replied that no thicker fire than usual was needed; the force of the blast in entering was regulated by a throttle-valve on a horizontal spindle; this was placed in a central hole at the bottom of the fire, and by turning it round occasionally the smith could drop the ashes settled at the bottom of the fire into a chamber below the valve, into which the blast entered at the side of the chamber, leaving space enough below for the ashes, which were cleared out usually at the end of the day, or oftener if required. By this arrangement all difficulty of keeping the tuyeres clear was obviated.

The CHAIRMAN then proposed a vote of thanks to Mr. Beyer for his paper, which was passed.

The following Paper, by Mr. John E. Clift, of Birmingham, was then read:—

ON AN IMPROVED PRESSURE GAUGE FOR STEAM AND WATER.

The Pressure Gauge which is the subject of the present communication is the invention of Mr. James Webster, of Birmingham, and appears to possess some practical advantages deserving of notice.

The Gauge acts upon the principle of a circular elastic plate receiving the pressure on one side, the plate being fixed round the circumference, and registering the amount of pressure by the extent to which it is displaced or bulged in the centre. The extent of motion of the plate is multiplied by a simple contrivance, and communicated to an index, which shows the amount of pressure by its revolution round a dial.

This pressure gauge differs from others acting upon the same principle, mainly in the increase of the area of the plate upon which the pressure acts and in the mode of multiplying the motion, which

appears to possess some advantages in simplicity, directness of action, and durability of the parts.

The construction of the gauge is shown in the accompanying drawings, Figs. 1, 2, 3, and 4, Plate 21; specimens are also exhibited of the different forms of the gauges, complete, and with the outer case removed to show the interior.

Fig. 1 is a front elevation of a pressure gauge for steam or water, extending up to 200 lbs. per square inch, drawn one quarter full size.

Fig. 2 is a sectional elevation of the same with the dial removed, drawn half full size.

Fig. 3 is a longitudinal section of the gauge, half full size.

A is the pressure plate, consisting of a circular flat plate of tempered spring steel, No. 18 wire gauge, or about 1-20th inch thickness, and 4 inches clear diameter, or 12¼ square inches area, in the central unsupported portion upon which the pressure that has to be measured acts.

This plate is fixed in a circular cast-iron frame BC by screws round the circumference, which press the outer ring C upon the plate, and make a tight joint at the back of the plate by means of a thin washer of vulcanised india-rubber.

The back part B of the case has a shallow recess, 4 inches diameter, communicating by a channel D with the stop-cock E at the bottom of the gauge; and this recess becomes filled with water, from condensation of the steam, when employed to measure steam pressure, and always remains full of water on account of the channel D entering at the top of the recess, thus preventing the direct contact of the steam with the pressure plate A.

A small steel stud F is fixed in the centre of the plate A by a screw and nut, and is formed with a knife-edge bearing at the top, pressing against the back of the lever G; this is centred on a bracket H at one end, and presses upon a second lever I by a knife-edge bearing at the other end.

The sliding bracket H, on which the lever G is centred, is fixed by a screw upon the ring C, and has an adjustment by a slot, as shown in Fgi.2, by means of which the length of the short end of

the lever from the point of contact of the centre stud F can be increased or diminished as may be required.

The lever I terminates in a fork which works up and down the centre spiral L, upon the extremity of which is fixed the index revolving on the face of the dial.

The fork at the end of the lever I is shown detached in Fig. 4, and is made of two tapered steel rods which enclose the spiral L, and press lightly against it by their elasticity; the ends of the rods being steadied by a small clip joining them together.

The spiral L makes one turn only in its whole length, and is gradually tapered and shortened in the pitch towards the outer end, so as to adapt it to the motion of the levers, and give a uniform division for the successive pressures indicated upon the dial.

When the pressure is admitted to act upon the back of the steel plate A, the plate becomes convex, rising in the centre and pressing by the knife-edge stud F upon the lever G, which multiplies the motion 4 times; and this pressing on the second lever I again multiplies the motion 4 times (being 16 times total) at the end of the fork acting on the spiral L. This fork in traversing the length of the spiral, $1\frac{1}{8}$th inch, turns the index entirely round the dial, in a circle of 16 inches circumference. The total amount that the pressure plate is raised or bulged to produce this motion of 16 inches is 1-16th of $1\frac{1}{8}$th inch (the latter being the motion of the forked end of the second lever), amounting to 1-14th inch at the centre of the plate, or ·07 inch.

When the pressure is removed, the plate returns to its original position, and becomes again quite flat, and the levers are retained in close contact throughout by the spring M pressing on the second lever I, and bringing the index back to zero.

In this pressure gauge the working parts are all of comparatively large size, having consequently an advantage in strength and durability; they have also great simplicity in construction and action, and appear very free from liability to derangement or accident.

The pressure plate A consists of a simple flat disc, and this form is considered by the inventor, from the results of his experiments, to have a practical advantage over corrugated plates, which have

also been extensively used for the same purpose, on account of the uniformity with which the flat plates can be tempered, whilst the corrugated plates are liable to have an inequality in the tempering, the more exposed portions at the tops of the corrugations being liable to be softer than the intermediate portions.

To meet the unavoidable variation in the tempering and resistance of the steel plates, even when plain flat plates are used, the position of the fulcrum of the first lever G is shifted by moving the sliding bracket H, by means of which the range of the instrument can be readily adjusted. Each gauge is separately adjusted in this way, by the application of actual pressure, so as to ensure accuracy of the indication in each case.

The steel plates are all capable of standing more than double the pressure indicated by the extreme range of the dial, without receiving any permanent set; and it appears from an extensive series of trials made by the inventor, that no perceptible change of elasticity is produced by long exposure to alternations of pressure and continued pressure within the limit.

A different thickness of plate is employed for gauges having different ranges of pressure, the area of plate exposed to the pressure being the same in all cases, namely, 12¼ square inches.

No. 18 wire gauge, or about 1-20th inch thickness, is employed for pressure gauges extending to 200 lbs. per square inch.

No. 20 wire gauge, or about 1-30th inch thickness, for 60 lbs. per square inch.

No. 23 wire gauge, or about 1-40th inch thickness, for 20 lbs. per square inch.

The extreme deflection of the plate in each case is only about ·07 inch, or little more than 1-16th inch.

The following results have been obtained by trial of the plates under successive pressures by a hydraulic press, the pressure being measured by weights upon a lever multiplying 4 times.

A modification of this pressure gauge is shown in Figs. 5, 6, and 7, Plate 22, and the specimens exhibited, in which a spring is employed to measure the pressure at the end of a safety valve lever,

Thickness.	Pressure.	Deflection.	Set.
18 Wire Gauge.	0 lbs. per square in.	·00 ins.	—
	50 „	·03 „	—
	100 „	·05 „	—
	150 „	·06 „	—
	200 „	·07 „	—
	300 „	·09 „	—
	400 „	·10 „	—
	500 „	·11 „	—
	600 „	·12 „	No Set.
20 Wire Gauge.	0 „	·00	—
	50 „	·03 „	—
	100 „	·05 „	—
	150 „	·07 „	—
	200 „	·09 „	No Set.
	800 „		·08 Set.
23 Wire Gauge.	0 „	·00 „	—
	10 „	·02 „	—
	20 „	·03 „	—
	50 „	·08 „	No Set.

as in an ordinary spring balance, and the indication is multiplied by means of the spiral L, without the intervention of any lever. The spiral is moved by the forked rod I, and the motion is communicated to the revolving index by the bevilled pinions O.

A considerably stronger spring than usual is employed in this case, having only 1¼ inch extent of motion, which is multiplied to a circumference of 12 inches upon the dial.

The advantage aimed at in this balance is that the spring does not require to be extended so much as in the ordinary balance, owing to the introduction of the multiplying spiral, and consequently the steel being less strained is less liable to a permanent set in the course of long work; also the indications of pressure are rendered more plainly visible by the motion of the index upon the dial.

Another adaptation of the spiral is shown in Figs. 8 and 9, Plate 22, and specimen exhibited, where the spiral is applied to the indication of the level of the water in a boiler or a tank.

A hollow copper float P lies upon the water, the lever of which is attached to a forked lever I at right angles to it, which works upon the spiral L; and as the float sinks with the water, the lever I acting upon the spiral L causes the index to revolve upon the dial.

The forked end of the lever I working loosely upon the spiral, and the continual motion of the water in the boiler keeping the float and spiral in constant action, prevent any tendency to stick fast; and the friction is confined to the small conical collar on the spindle of the spiral passing through the side of the boiler, by means of which the joint is kept tight by the internal pressure.

This water gauge has an advantage over the ordinary glass gauge in the indication being always readily seen, as when the water becomes muddy or the glass soiled the level is not so easily ascertained in the tube; also by enlarging the diameter of the dial, each inch of variation in the level of the water in the boiler can be magnified to two inches, or more if desirable.

A specimen of the pressure gauge was exhibited, and put in action by means of a force pump; also specimens showing the construction of the gauges, and the steel plates that had been experimented upon.

The CHAIRMAN remarked that he had tried the improved spring balance that had been described, and it was certainly more plainly visible in the indications of pressure than the ordinary Salter's spring balance, but he did not see that it was superior in accuracy or durability of the spring; he had had balances of Salter's indicating up to 180 lbs., and they were not found to get set.

Mr. CLIFT considered Salter's balance was liable to get out of order, owing to the extent to which the spring was stretched, which caused it to be liable to be sometimes strained, and consequently rendered inaccurate; he thought the small extent of motion in the improved spring balance would prevent the spring from getting set at all.

The CHAIRMAN did not think too great an extent of motion was allowed to the spring in Salter's balance, as he had not found any cases of these balances becoming set and thrown out of adjustment, even after being a long time in use; the springs were very excellently tempered, and the least likely to get out of order of any that he had tried.

Mr. JOY observed that range of indication was not the only requisite in a spring balance, but also range of lift for the valve itself, to give free relief to the steam blowing off; if the range were shortened, there would not be sufficient area of escape for the surplus steam, and the pressure would rise considerably beyond the limit intended to be used. He had known the pressure rise 25 lbs. during blowing off, and in one case where 2½ inches range of spring had been allowed for a limit of 120 lbs. pressure, the increase had been 20 lbs. during the blowing off.

Mr. WEBSTER remarked that the dial might be adapted to any range of spring that might be required, by simply increasing the pitch of the multiplying spiral.

Mr. HODGE thought that the Diaphragm pressure gauges, registering by the deflection of a circular steel plate, such as Schaeffer's and the one described in the paper, were quite equal to any in use; the arrangement in Mr. Webster's gauge appeared very good, and had some decided advantages over the other kinds of gauges in use.

Mr. WEBSTER observed that the principal feature in his own gauge was the use of a larger and stronger diaphragm, in consequence of which the extent of motion and strain upon the particles of the plate was so much diminished, that the risk of permanent set by constant use was prevented.

The CHAIRMAN asked to what extent the steel plates were tempered.

Mr. WEBSTER replied that they were first hardened, and then tempered down to just below a straw colour, so that the file would just touch them; the gauge was then adjusted to the elasticity of the plate, by means of the moveable slot carrying the end of the first multiplying lever. All the plates were proved by a hydraulic press up to double the pressure they were required to register.

Mr. SHIPTON inquired whether the india-rubber cloth at the back of the plate, being an elastic material, was not found to yield after wear, and

affect the fixing and adjustment of the pressure plate; and he asked whether the gauge had been tested by continual exposure to high-pressure steam for a considerable time.

Mr. Webster stated that the india-rubber cloth was used only for the joint at the back of the pressure plate; tin and lead had been tried, but the cloth was found to be preferable, and either a complete disc or an annular ring was employed. The cloth got fully stretched during the testing of the plate, and so did not yield any more afterwards; the thickness in the joint was so small that it could not alter. Each gauge was tried, when made, by subjecting it repeatedly to a pressure double of that at which it was intended to be worked, which would thoroughly bring all the parts to a bearing. He had tried a gauge under a constant water-pressure of 150 lbs. per inch for 3 days successively, but did not find any yielding of the india-rubber joint.

Mr. Rofe inquired whether the india-rubber cloth was not liable to get burnt by the high temperature of the steam.

Mr. Webster replied that in consequence of the back of the gauge being always kept full of water, by means of the syphon passage for the admission of the steam, the pressure plate was always protected from contact of the steam, and consequently remained cool, so that the cloth was not injured.

The Chairman remarked that the present pressure gauges were sometimes found to lose their elasticity, and inquired whether this was not the case also with Mr. Webster's.

Mr. Webster answered that when the plates were made of proper thickness, suitable to the pressure required, and well tempered, they retained their elasticity, and exhibited no tendency to a permanent set after long-continued use. The plate exhibited, which had a permanent set of ·08 inch, had been made of too thin metal; and that which was burst had been tempered too hard. The tempering of the plates required great accuracy and certainty in pressure gauges, and this could be more perfectly accomplished with the thicker plain plates that he employed, than with the thinner corrugated plates, which he had found liable to be rather softer at the tops of the corrugations than at the intermediate portions. The thinner plates were also more liable to set than the thicker ones, and by using the plates of No. 18 wire gauge the tendency to a permanent set was entirely removed.

Mr. Hodge stated that the Russian engineers appeared to be in favour of diaphragm gauges, as circular steel plates had been adopted for the Government pressure gauges; the plates were of large size, he believed 9 or 10 inches diameter.

Mr. Clift remarked that in Schaeffer's pressure gauge, the disc, of about 24 wire gauge, was corrugated in circular corrugations, but in the one described in the paper, the disc was flat and about three times the area. The flat discs could be tempered uniformly throughout, and he had been struck with the perfection with which they retained their elasticity in the several severe trials. He mentioned that the pressure gauges were being manufactured by Messrs. Gray and Bailey, of Birmingham.

The Chairman observed that the uniform temper of the elastic plate was a point of great importance for ensuring permanent accuracy, and he thought this advantage, and the simplicity of its construction, rendered the gauge a very serviceable instrument. He proposed a vote of thanks to Mr. Clift for the paper, and to Mr. Webster for his specimens, which was passed.

The following Paper, by Mr. Thomas Richards, of Birmingham, was then read :—

ON AN EQUATORIAL MOTION FOR TELESCOPES.

The object of the apparatus that forms the subject of the present paper, is to provide the means of giving a self-acting Equatorial Motion to an ordinary telescope, so as to enable the observer to keep any celestial body in the field of view, by a simple and inexpensive addition to the ordinary telescope and stand, and without requiring a previous knowledge of the position of the true meridian, or the latitude of the place of observation. The only method hitherto of accomplishing this object, has been by means of a permanent fixed axis, set parallel to the earth's axis, as is the case in fixed observatories, where both the position of the true meridian and the latitude of the place of observation have been previously ascertained;

but with the apparatus about to be described, the preparation of the instrument occupies only a few minutes, and can be readily effected at the time by any observer.

This apparatus may consequently be not inappropriately called "the Portable Observatory," as it enables any one possessing an ordinary telescope mounted on a tripod stand to make a continuous observation of a celestial body, wherever he may happen to be, without having to touch the telescope after having once brought the object into the field of view.

The apparatus complete is before the meeting, and is also represented in the drawings, Plate 23, Figs. 1, 2, and 3.

In order to obtain an equatorial motion for the telescope, the first thing to be done is to set the axis about which it is to turn truly parallel to the earth's axis, because then any point in the axis of the telescope itself will move truly parallel to the equator, at whatever elevation the telescope may be set.

For this purpose, on an ordinary tripod stand A, Figs. 1 and 2, is mounted a tube B, shown in section, in such a manner as to admit of both a horizontal and vertical angular motion, both of which can be firmly clamped in any position. In order to adjust the instrument suitably for the equatorial motion required, a small finder-telescope C is first inserted in the tube B, being made to fit it accurately by means of bell-metal collars fitting into corresponding bearings at the ends of the tube. The diaphragm which circumscribes the field of view of the finder has its centre, of course, in the axis of the finder; its diameter is 2° 57′, being double the north polar distance of the Pole star; consequently the field of view of the finder, shown by the dotted lines in Fig. 2, takes in a circle exactly equal to that apparently described by the Pole star round the pole; and therefore, when the circle described by the Pole star coincides with the circumference of the field of view of the finder, the axis of the finder will be parallel to that of the earth.

In order to make the circle described by the Pole star coincide with the circumference of the field of view of the finder, a small brass sector or arm D, shown in elevation in Fig. 3, is slipped over the finder, as shown in Fig. 2, having two small holes in it, and a

narrow radial or longitudinal slit, which serves the purpose of an index. When two of the stars of the Great Bear constellation, namely, ϵ and ζ Ursæ Majoris, are seen through the two small holes of the sector, by the eye of the observer at E, then the longitudinal slit or index points out that point of the edge of the field of view of the finder, to which the Pole star must be brought, by adjusting the finder by hand. This point will be apparently the one on the *same* side as the two stars ϵ and ζ, since the position of the Pole star, which in reality is on the *opposite* side of the pole to the two stars above named, is *inverted* by the finder, which is a small ordinary astronomical telescope. When the finder is so adjusted that the Pole star is seen at the point thus indicated, at the same time that the two stars ϵ and ζ are seen through the two holes in the sector D, then the axis of the finder, and consequently of the tube B encas ing it, is parallel to the earth's axis. The horizontal and vertical motions of the tube B are then clamped.

The accuracy of the adjustment may be tested by turning the finder C round its own axis, when the Pole star ought to remain stationary at the same point in the circumference of the field of view. If this be not the case, the adjustment must be corrected according to the deviation of the Pole star from a stationary position.

The finder C with the sector D is now removed, and the axis F of the large telescope G is inserted in the tube B, as shown in Fig. 1. The axis F is made to fit the tube accurately, in the same manner as the finder C, by means of bell-metal collars fitting accurately into the corresponding bearings at the ends of the tube. Any point in the axis of the telescope will now move truly parallel to the equator, whatever inclination it may have to its axis F; and consequently, when directed to any celestial body, it will truly follow the apparent course of that body, if turned round about the axis F at a fixed inclination and at a suitable uniform rate of motion.

To produce the required motion, the Right Ascension Circle or wheel H is fixed on the end of the axis F; and underneath the stand A is placed a cylindrical pan of water I, containing the float K, the gradual descent of which, as the water runs out, communicates motion to the right ascension circle H, by means of the cord L passing over the pulley M. The

water runs out of the pan I through the syphon N, which is carried by the float K, so that the surface of the water is lowered at a uniform rate, the syphon descending with the water. This portion of the apparatus is, in fact, simply a revival of the ancient clepsydra.

The right ascension circle H has two grooves on its rim, the upper of which is exactly 24 inches in circumference, and the lower 25 inches nearly, these numbers being in the proportion of the sidereal to the mean lunar day. If the motion of the moon is to be observed, the cord L is placed in the lower groove; if that of a star, in the upper; it is slightly tightened in the groove by means of a small clamp, and the loose end hangs by a plummet over a pulley fixed in one of the legs of the stand. The thickness of the cord should be twice the depth of the grooves. The pulley M can be raised and lowered, so as to be always in the plane of the right ascension circle H, when the latitude of the place of observation is changed.

The pan I is about 18¾ inches in diameter; it contains 95¾ pints in a depth of 12 inches. This quantity of water should be run off by the syphon N in 12 sidereal hours. The rate (which should be adjusted while the telescope is in motion) is determined by raising or lowering the syphon by means of a rack and pinion fixed to the float K. When adjusted, the syphon must deliver 1 gallon in 1 mean solar hour, or 1 pint in 7½ minutes.

When the syphon is first set in action, no motion will be imparted to the telescope, until the cord L is stretched sufficiently to overcome the friction of the collars of the axis F in the tube B, and the inertia of the instrument. A stop-cock O is therefore provided, which is opened just at starting, thereby causing the float to sink rapidly; as soon as the body to be observed appears in the centre of the field of view, the stop-cock is closed, and then the action of the syphon alone gives sufficient motion to the telescope to cause the body to remain apparently stationary in the field of view.

As it is found that differences in the temperature of the water occasion some little variation of rate in the quantity delivered by the syphon, the rack and pinion should be graduated for such differences; or a self-regulating clepsydra might be constructed, either by using two cisterns and two syphons, one of the latter acting as a supply-pipe to the cistern

containing the float connected with the telescope, in which case, since the difference in temperature affects both syphons alike, the difference in the rate of flow through them, which determines the rate of descent of the float, remains constant;—or if one cistern only be used, by a thermometer carrying a piston attached to the syphon, the bulb of the thermometer being fixed underneath the float.

If the telescope be not well balanced about its centre of gravity, more or less weight will be required to move it, as its direction is varied, and consequently its motion will not be uniform. If, however, the float cover a large surface of water, and the syphon when adjusted for the mean temperature be immersed to some depth below the surface, no perceptible variation of rate will be occasioned.

The action of the clepsydra produces a smoothness of motion not to be surpassed, and might be adapted with advantage to the requirements of an observatory, more especially as its rate may be so readily brought under the immediate control of the observer.

It is to be remarked, that, independently of its application to the production of equatorial motion, the instrument above described, or more correctly the portion first described and exclusive of the clepsydra and of the parts connected with it, is designed to show a new and simple method by which an extended wire, the axis of a tube, or of a telescope, may be made parallel to the earth's axis, to a sufficient degree of accuracy to render it available for astronomical observations.

Other simpler forms might be adopted, by which one telescope only need be used, or a telescope and its finder; in the latter case, the finder having a field of view of $2^\circ\ 57'$ would enable the observer to determine the polar axis, and might be so mounted as not to require to be removed when the adjustment had been made. Where very powerful telescopes are used, the smaller one, for finding the polar axis, might have a field of view of 3°, and the exact position of the Pole star within the circumference might be determined by a micrometer adapted for the purpose; this would admit of the requisite correction being made for refraction. Such a telescope, attached in the same manner as a finder to the present Polar axes in observatories, would serve to test the accuracy of their position; while in Fraunhofer's form of Equatorial, (which is so arranged that the telescope will reach every part of the heavens without being

interrupted by the framing or stand on which it is carried,) it might be substituted for the Polar axis, whereby the optical axis of one telescope would be made the fixed axis, about which the other telescope would revolve.

Mr. Hopkins exhibited his instrument to the meeting, and illustrated the method of adjustment, and mode of action.

The Chairman observed that it was undoubtedly a great advantage to be able to obtain a self-acting motion for an ordinary telescope, and by such as imple method as that proposed, the gradual descent of the water in tho cylindrical pan, which was a beautiful mechanical contrivance for obtaining a regular and steady motion; and the addition of the apparatus to the ordinary telescope would greatly extend its utility.

Mr. Hopkins said he had found the instrument of great use in observations on the celestial bodies, and it answered the purpose intended very completely; the rate of the syphon was in practice set slightly slower than that of the stars, so that in case the observer left the telescope for a time, and on returning to it, found that the body he had been observing was no longer in the field of view, he would know that it must be in advance of the telescope, and he had simply to open the cock at the side of the pan, and run off a little more of the water, when the telescope would directly overtake the body, and the latter would again appear in the field. The two grooves in the right ascension circle enabled the observer to adapt his telescope to the moon or the stars, with the same adjustment of the syphon; if there were only one groove, the syphon would have to be readjusted separately for the moon and stars, which would be a troublesome process.

The Chairman asked whether a very large quantity of water would not be required, or a frequent filling up of the cistern, in the case of large instruments, in order to overcome the variable friction of the moving parts, and insure a steady motion; if this were required, the apparatus would then become inconveniently large.

Mr. Hopkins replied that where large telescopes were used, they might easily be so balanced about the axis of motion, as to render the

friction to be overcome by the descending weight very nearly uniform. In the case of large instruments, he would also propose placing the syphon in a large detached tank, in any convenient protected situation, and connecting the water by a gutta-percha tube with the small pan attached to the telescope to impart the motion.

The CHAIRMAN inquired whether difference in the temperature of the water did not affect the motion communicated to the telescope.

Mr. HOPKINS stated that he had found by careful experiment that the difference of temperature had no perceptible effect, when the bore of the syphon was more than $\frac{1}{4}$ inch in diameter; but when less than that, the difference did affect the rate of flow through the syphon. With a syphon 3-16ths inch bore, at 62° Fahr., 1 pint of water flowed through in 151 seconds; but at 82°, the same quantity flowed through in 134 seconds; being a diminution of 17 seconds in the time, for an increase of 20° in the temperature.

Mr. OSLER said he had seen the apparatus in operation on the previous day, and its action was very perfect and steady; he thought a simple and inexpensive equatorial motion was a great desideratum for ordinary telescopes; the clock-motion that was employed for the purpose was expensive, and beyond the reach of observers in general. This motion was generally adjusted slightly too fast, and was retarded by a check-string held in the observer's hand, whenever required to bring the object into the field of view; in Mr. Hopkins' apparatus, the adjustment was effected in the contrary way, by accelerating the motion when required by means of the regulating cock at the bottom of the pan. The objection most likely to be made to Mr. Hopkins' plan was that the water would freeze, when observations were made out of doors, as was most convenient inmany cases; but this might not prove any serious difficulty. In an observatory, the temperature might be kept up by artificial means, but this was objectionable, for the reason that the heated air, rising from the room, caused a flicker in the field of view. He suggested that the difference in the velocity of flow through the syphon, under different temperatures, was due to the difference in the density of the water, the water becoming more fluid as its density was diminished by heat, and more viscid as it was increased by cold.

Mr. HOPKINS said he had never experienced any difficulty from the freezing of the water, and in ordinary cases it was not likely an ob-

server would remain at the instrument so long as would be requisite for the water to be cooled down to the freezing point; and even if it were desirable in severe weather to provide specially against this, it could be readily done by the addition of a little hot water in the pan, to raise the temperature at first; and the only inconvenience resulting would be the slight diminution in the rate of motion as the water cooled, which would be an error on the right side, as it would be instantly rectified by slightly opening the extra discharge cock at the bottom of the pan.

Mr. S. Lloyd, jun., suggested that salt water might be used in the pan, as less liable to freeze.

Mr. Hodge thought the apparatus was very ingenious, and a beautiful mode of giving a smooth regular motion; he did not think any difficulty from freezing need be apprehended, as various liquids might be employed, such as a mixture of alcohol and water, which would prevent the risk of freezing.

Mr. W. R. Wills said he had had an opportunity of examining the instrument in operation, and had been much surprised and pleased with the perfect uniformity of motion communicated by the flow of the water; uniformity of movement having been obtained, he thought that the action of the machine would be smoother than that of any clock-motion. He had not had an opportunity of observing a star with the instrument, but had watched its steady and almost imperceptible motion in traversing across a stationary object.

The Chairman remarked that it was essential that the body observed should appear quite stationary in the field of view, which could only be effected by securing a perfectly uniform and steady motion for the telescope, and this appeared to have been effectually accomplished by Mr. Hopkins, and the simplicity of his apparatus was a great recommendation.

He proposed a vote of thanks to Mr. Hopkins, which was passed.

The Chairman announced the presentation to the Institution Library of the Lowell Hydraulic Experiments, by Mr. James B. Francis, of Lowell, U. S.; and of a large Drawing of the Pumping Engine of the Wolverhampton Water Works, by Mr. Henry Marten, of Wolverhampton.

The Meeting then terminated.

PROCEEDINGS.

OCTOBER 24, 1855.

The GENERAL MEETING of the Members was held at the house of the Institution, Newhall Street, Birmingham, on Wednesday, 24th October, 1855; WILLIAM FAIRBAIRN, Esq., F.R.S., President, in the Chair.

The Minutes of the last General Meeting were read by the Secretary, and were confirmed.

The CHAIRMAN announced that according to the rules of the Institution, the President, Vice-Presidents, and five of the Council in rotation would go out of office in the ensuing year; and that at the present Meeting the Council and Officers were to be nominated for the election at the next Annual Meeting.

The following list of Members was adopted by the Meeting for the election at the next Annual Meeting.

PRESIDENT.

JOSEPH WHITWORTH, Manchester.

VICE-PRESIDENTS.

(*Six of the number to be elected.*)

SAMUEL H. BLACKWELL, Dudley.
WILLIAM FAIRBAIRN, Manchester.
BENJAMIN FOTHERGILL, Manchester.
JOHN HENDERSON, Birmingham.
SAMPSON LLOYD, Wednesbury.
JAMES E. MCCONNELL, Wolverton.
JOHN PENN, London.
JOHN SCOTT RUSSELL, London.

COUNCIL.

(Five of the number to be elected.)

Charles Beyer, Manchester.
John E. Clift, Birmingham.
Alexander B. Cochrane, Dudley.
Benjamin Fothergill, Manchester.
Sir Charles Fox, London.
Edward Jones, Liverpool.
John Ramsbottom, Manchester.
Archibald Slate, Middlesboro'.

The following Paper, by Mr. George M. Miller, of Dublin, was then read :—

DESCRIPTION OF A NEW EXPANSIVE VALVE MOTION FOR STEAM ENGINES.

The object of the valve motion described in the present paper (the invention of Mr. John Wakefield, of the Great Southern and Western Railway, Dublin), is to obtain an expansive action more simple and more perfect than the motion usually employed, the whole motion being obtained from a single eccentric upon the crank shaft.

The general arrangement of this valve motion consists of an eccentric, which, instead of being keyed upon the axle in the ordinary manner, is mounted upon a transverse slide, which is capable of being moved at right angles to the axle by means of a handle that takes the place of the ordinary reversing handle or lever. The effect of moving the transverse slide is to alter the throw of the eccentric or to reverse its position, thereby enabling the valve of the one engine or cylinder to which it belongs to be worked expansively or reversed. The valve of the second engine or cylinder (in the case of the usual pair with cranks at right angles to each other) is worked by a second rod connected with the same eccentric by means of an arm projecting at right angles to the direction of the first eccentric rod, so as to give to both valves a similar motion, but corresponding to the relative position of the two cranks at right angles to each other.

The construction of this apparatus is shown in Plates 24 and 25, which represent it as applied to a locomotive engine.

Fig. 1, Plate 24, is a plan of the valve motion.

Fig. 2 is a longitudinal elevation of the axle, showing the valve motion in section.

Figs. 3, 4, and 5, Plate 25, are transverse sections of the axle, showing in detail the different portions of which the valve motion is composed.

Fig. 7 is a general view to a smaller scale.

All the figures show the apparatus in the position of full backward gear.

Upon the crank axle A, Figs. 1 and 2, and close up against one of the cranks, is fitted a concentric collar B, fixed to the axle either by keys, or by screws tapped into the crank cheek through lugs cast on the collar on the side next the crank. On the other side of the collar are cast two parallel bevilled slides, shown in Fig. 6, situated transversely and equidistant from the centre of the axle. Upon these is fitted a corresponding sliding frame C, carrying a circular ring cast upon it projecting from its face, which is situated not equidistant between the two parallel slides, but is set eccentrically, that is, nearer to one slide than to the other, by the amount of the minimum throw of the eccentric. The circular ring on the frame C thus takes the place of the ordinary eccentric, and is fitted with the eccentric strap D, on the front edge of which is forged the end of the rod E, by means of which the spindle of one of the valves is worked. On the back edge of the eccentric strap, and in the same straight line with the eccentric rod, is forged the slotted arm F, having a horizontal slot fitted with a slide block. In this is inserted a pin, projecting from the arm G of the loose ring H, concentric with the axle and working in a groove in the fixed collar B previously described. The ring H is furnished with a second arm, at right angles to the arm G, and also with a balance weight I. To the second arm is attached a rod K, similar to the eccentric rod E, by which the spindle of the second valve is worked.

The transverse section, Fig. 3, shows in detail the loose concentric ring H on the fixed collar B, the arm G with the projecting pin, and the second arm at right angles to G, with the rod

K attached; also the balance weight I on the opposite side to the arm G. Fig. 5 shows in detail the sliding eccentric ring, fitted with the eccentric strap D, on the back edge of which is the slotted arm F with the slide block.

The reversing action is effected by the lever L, Fig. 2, which is worked by means of an ordinary reversing handle. The lever L is attached to a loose strap or clutch, fitting in a groove in the collar M, which is free to slide along the axle, but is caused to revolve with it by means of the two feathers NN, Fig. 5. The collar M carries two racks, which drive the two pinions OO, Fig. 4. These pinions are screwed internally to fit on two large four-threaded screws, which are secured in the sliding frame C previously described. The pinions OO are placed in cavities in the fixed collar B, and thus are incapable of any lateral motion. In reversing the engine, the collar M is caused to slide along the axle by means of the lever L, and the racks cause the pinions OO to rotate; the screws being held in the sliding frame C so as to be incapable of turning, a transverse motion is communicated to the frame, which, with the eccentric ring attached to it, is carried along the parallel slides, thus reversing the position of the eccentricity. The reversing lever is moved with greater facility than is usually the case with the link motion.

When the eccentric ring is giving the greatest horizontal motion to the eccentric rod E, the slotted arm F has its least vertical motion, and consequently, since it is the vertical motion alone of the slot which affects the arm G, the latter is at this time stationary, and therefore the arm at right angles to it is also stationary, and the rod K has no horizontal motion. In like manner, when the eccentric rod E has no horizontal motion, it has the greatest vertical motion, as also has the slot F, and this being communicated through the right-angled arms of the ring H, causes the rod K to have its greatest horizontal motion.

It has to be observed that with this motion the engine can never be thrown entirely out of gear. When the engine is reversed, the centre of the eccentric describes a *chord* line (Figs. 4 and 5), not the *diameter* of the circle of eccentricity, and consequently the minimum to which the throw can be reduced, is the distance of this chord line from the centre of the axle, or the sum of the lead and

lap of the slide; but the same circumstance applies to the ordinary link motion, and although, for this reason, the expansive action of the steam cannot be extended indefinitely, yet practically this is no objection to the valve motion, since between the positions of maximum and minimum throw, it admits of as great a range for the application of the expansive principle as can be made practically available where the link motion is employed.

In the new valve motion the lead is constant for all positions of gear, whilst in the ordinary or shifting link motion it varies to a certain extent with every change of position, increasing as the throw of the valve diminishes; in the new valve motion, accordingly, the expansive action alone is altered by regulating the amount of throw, whilst the lead is not affected by the change.

A modification of the above valve motion is applicable to stationary and marine engines, in which a bell-crank lever is introduced, for the purpose of giving the motion to the second valve rod in a position parallel to the first, instead of an inclined position as before described; see the rod K, Fig. 3.

The simplest arrangement would be to have the two cylinders placed at right angles to each other, working upon the same crank pin; in this case the two valve rods would be worked direct by the one eccentric, their direction at right angles to each other obviating the necessity for the intermediate arms or levers introduced in the former arrangements.

A practical trial of this valve motion has been made in two locomotive engines on the Great Southern and Western Railway, which have been working with it $1\frac{1}{2}$ year and $1\frac{1}{4}$ year since March and July, 1854.

One of these, a Passenger engine, is fitted with the new motion as shown in the drawings and model. In the other, a Goods engine, a slight modification has been made, the construction being simplified by dispensing with the slotted arm F, projecting from the back edge of the eccentric strap D, and substituting a similar slot in the eccentric rod E; the arm G of the loose concentric ring H is thus brought round to the front, and the balance weight I is placed behind.

The Passenger engine, No. 9, has 15 inch cylinders with a 20 inch stroke, and 5 ft. 6 ins. driving wheels; it has been working regularly between Dublin and Thurles (a distance of 87 miles), with two other engines, Nos. 17 and 19, by the same maker, and similar in all respects, except that they are furnished with the ordinary link motion.

The results of the working of these three engines during the 1½ year from the 18th March, 1854, to 12th October, 1855, are as follows:—

	Miles run.	Coke per mile. lbs.	Average load. Carriages.
No. 9	44,450	20·3	6·0
No. 17	42,741	23·6	5·9
No. 19	27,194	24·9	5·8
Mean with link motion		24·25	5·85
Mean with new valve motion		20·03	6·00

The carriages are six-wheeled, and weigh seven tons empty.

A comparison of the results of the performance of these engines for the periods before stated shows an average saving in consumption of coke of 4¼lbs. per mile or 17½ per cent. in favour of the engine having the new valve motion.

The Goods engine, No. 53, has worked well, but the variable character of the work assigned to the goods engines on the above line renders it difficult to compare their performance.

It will be observed that the first engine (No. 9 Passenger engine) fitted with the new valve motion, has now had it more than 1½ year in constant work. The motion has undergone no repair during the whole time, except that a thin lining of white metal has been recently put upon the face of the bevilled slides, which had worn a little slack, having been in the first instance made of brass. In the subsequent engines cast iron has been used for these slides. No other repair to the motion has been needed, and it is still working in good order.

The second engine (No. 53 Goods engine) has been more than 1¼ year in constant work with the new valve motion, and has run during that time 23,581 miles; this motion has had no repairs, and has never even been taken to pieces and examined since first got to work until a fortnight ago, and when the parts were then detached for inspection they

were found in excellent condition, the working faces all in good order, the teeth of the racks and pinions showing no signs of wear, and the whole play of the apparatus amounting to only about $\frac{1}{16}$th of an inch, being little more than it had when originally set to work. This motion seems likely to work for more than the usual time before needing repairs, and the small amount of wear in it is remarkable as compared with the ordinary link motion, which appears to arise from the large extent of rubbing surface, and the fact that the whole is held firmly between side cheeks and steadied by them whilst in motion; the working parts are also enclosed and protected from dust.

It may be thought that the application of this new motion encumbers the crank axle with more complex machinery than is the case when four eccentrics are used; but it must on the other hand be observed that the remainder of the space under the boiler is left more free for examination and cleaning; also the eccentric rods have at all times only the same extent of motion as the valves, whilst with the link motion most of the working parts reciprocate over the same space, whether the engine be working expansively or not.

Mr. Miller exhibited a working model of the new valve motion, showing it as applied to a locomotive engine.

The Chairman observed that the subject of the paper was one of importance, and from the particulars given the new motion appeared to have some advantage in durability and working; the comparative saving of fuel stated in the paper was considerable, but might probably be partly owing to other causes than the new motion alone. He had seen the motion about twelve months ago, on an engine upon the railway at Dublin, but it had then been only a few months at work, so that the results of the working had not been sufficiently ascertained. He enquired whether any more engines had been furnished with the new motion, besides the two mentioned in the paper, and whether any further particulars of the working had been obtained.

Mr. Miller replied that it had been applied to three more engines on the Great Southern and Western Railway, but these had

been at work only a few weeks, and consequently no results had yet been obtained. It had also been tried by Mr. Stephenson in an engine made for the North Eastern Railway about three months ago. The great saving of fuel which had been stated in the paper, was, he believed, correctly ascertained, but he was at a loss to account for so great a saving from the valve motion alone; he could suppose only that it arose from the circumstance that there were fewer joints in the new motion, causing less loss from play after wear than in the link motion. The movement imparted to the valves was not quite the same as in the link motion, and he considered that it was more correct than that given by the link, on account of the lead remaining the same; there was some difficulty in getting the link motion to work truly in all positions of gear, and the greater exactness with which the new motion worked in the different degrees of expansion might partly explain the economy effected with it. In the engine from which the results in the paper had been taken, the steam had been cut off to the same extent as in the corresponding engine with the link motion, the lap of the valve being $\frac{9}{16}$ths inch, and the lead $\frac{1}{4}$th inch. He intended to take some indicator diagrams from the engines fitted with the new motion, and these would show distinctly what difference there was between its action and that of the ordinary link motion.

The Chairman said it was important that some indicator figures should be taken, for the purpose of comparison; that was indeed the only method of satisfactorily examining the working of the new motion. He asked whether the new motion was applicable to any kind of engine.

Mr. Miller answered that it might be adapted to any engine, and a form applicable to marine engines was shown in the drawings; but it had been tried at present only for locomotives.

Mr. Cowper did not see how there could be any material difference in the working of the valves from that given by the link motion, as in the latter the lead was nearly constant. He thought the saving of fuel with the new motion, as far as it arose from diminished play in the valve gear, could be only small in amount; it must be due mainly to improved construction of the machinery

in general, or to working one engine more expansively than the other, or to greater care on the part of the engine driver to economize fuel, as a great difference was often found in the economy of an engine when worked by different men.

Mr. MILLER said that the circumstances in which the two engines had been placed, from which the comparative results had been obtained, had been as nearly alike as possible; their age and general condition were the same, and he believed they had been worked to the same degree of expansion and with the same care in both cases.

Mr. RAMSBOTTOM thought that the action of the new motion was nearly the same as that of Dodds' wedge motion, and differed so little from that of the link motion, that its superiority would be mainly a question of durability and maintenance, which could be decided only by long experience. In the link motion the lead became greater at a higher degree of expansion, but he did not consider this objectionable, but rather an advantage, as the greater lead was used principally for higher speeds. The arrangement of the new motion was ingenious, but he should fear the maintenance of it would involve an increase of expense.

Mr. MILLER said that the cost of maintenance had been found to be but little, and appeared to be decidedly less than with the link motion; the first engine had only had a lining of white metal put on the face of the bevil slides, during the whole 1½ year that it had been at work; and nothing at all had been done to the other, during the 1¼ year that it had been at work; whereas an ordinary link motion would have been much worn and have required considerable repair by that time. The difficulty with the wedge motion, arising from the objectionable strain thrown on the slides of the eccentric and on the wedge surfaces, did not exist in the new motion; the screws and pinions. which were the parts that had the greatest appearance of complication, were not exposed to any strain or work while the engine was running, and were moved only when it was required to reverse the engine or alter the degree of expansion; this circumstance alone would tend to greater durability.

Mr. FERNIE observed that the new motion appeared to him more complicated than the wedge motion, and he feared would be inferior to it, having a greater number of joints. He had had some experience of the latter on the Midland Railway, where four or five engines were running with it; there was a difficulty in keeping the motion in working order, and it had not proved any better than the link motion.

The SECRETARY mentioned that he had recently had an opportunity of examining the new motion at work, and had seen it at the time of being taken to pieces for the first time, as had been stated; there was not any appearance of wear in the teeth of the racks and pinions, nor in any other parts, though they had been in use for so long a time; the motion appeared to work well, and it was easy to reverse or alter the expansion.

The CHAIRMAN said he hoped that the action of the new motion would be investigated by means of indicator diagrams, so as to ascertain clearly its merits, and they would be glad to hear the further results.

He proposed a vote of thanks to Mr. Miller for his paper, which was passed.

The following Paper, by Mr. Edward A. Cowper, of London, was then read:—

DESCRIPTION OF A SET OF SIX BLAST ENGINES MADE FOR THE EAST INDIAN IRON COMPANY.

In accordance with the request of the Council, that each member should communicate to the Institution the particulars of any work of a novel character in which he may have been engaged, and that would be likely to prove interesting or useful to the members, the following description of a number of Blast Engines that have been recently made for blowing the furnaces of the East Indian Iron Company has been prepared by the writer; and as so many of our friends are engaged in the production of that one metal, which not only exceeds any other in

usefulness, but all the others put together, it is presumed, that if the construction of these engines is approved, this paper will be of some service.

These engines were made to the plans and under the superintendence of Mr. Charles May, the consulting engineer to the East Indian Iron Company, by Messrs. James Watt and Co., to the drawings prepared by the author of this paper.

The engines are six in number, two pairs of them being intended to blow air at 2 lbs. per square inch as a maximum pressure, and the other pair to blow air at 4 lbs. per square inch as a maximum pressure.

Fig. 1, Plate 26, is a side elevation of the engine complete, with crank-shaft, wheels, &c.

Fig. 2, Plate 27, is a vertical section through the steam and air cylinders, and their valves and passages, and the branch air pipes.

Fig. 3, Plate 28, is a plan, and Fig. 4 shows a sectional plan taken through the air valve, and the air passages and branch air pipes.

The two diagrams, Figs. 5 and 6, Plate 29, show the proportionate size of an ordinary blast engine and one of these engines to the same scale.

There are also indicator figures, Figs. 7, 8, and 9, taken from the air cylinder of an ordinary blast engine and the steam and air cylinders of the new engines.

The general form and construction of the engine is that of a "Pedestal or Table Engine;" the air cylinder A stands on a short pedestal, and itself forms the pedestal or table on which the steam cylinder B stands. The foundation plate is 6 feet square, and carries a wrought-iron crank shaft C in four plummer blocks, having two light fly wheels DD, one on each end of the shaft, and the two eccentrics EE for driving the air valve F, one on each side of the air cylinder, and the eccentric G for driving the steam valve H, in the centre. The steam piston has one piston rod fixed in a short cross head I at the top, and this cross head has two other piston rods for driving the air piston, which pass down outside the steam cylinder through stuffing-boxes in the cover of the air cylinder, and are attached to the air piston. The long cross head K, taking the connecting rods to the cranks, is attached to the short cross head by a pin, so as to allow a little freedom

in case of unequal wear; the guides L L are attached to the steam cylinder cover.

The air valve F is made under Mr. Archibald Slate's patent, and is a ring or crown valve entirely enclosing the air cylinder, and is not self-acting by the pressure of the air in any way, but is moved by the pair of eccentrics E E at the proper times, so as to give ample passage for the air to move with the greatest freedom, and the valve has such a proportion of lap as to cause the air to be compressed up to the working pressure before it is delivered, thus giving the engine no more work to do than is necessary.

The openings or passages for the air from the air cylinder to the valve are extremely short, and the bars between the openings are made inclined, so as to cause a regular wear on the brass packing rings which form the rubbing face of the valve. The body of the air valve is made of thin sheet iron, neatly curved to two turned cast-iron rings, to which it is well secured by a great number of small bolts; these rings are bored out inside to receive the brass packing rings before mentioned, which are secured in their places by bolts. There are no springs to the brass packing rings, but they are bored out to be a perfect fit to the outside of the air cylinder, and are then cut into eight pieces, and should any wear take place they can be at once adjusted by introducing a thin sheet of paper behind them and screwing them fast in their places again. It should, however, be remarked that this valve is under totally different circumstances from any that have hitherto been made, as it is perfectly in balance, or rather it is suspended perfectly freely, and slides up and down a turned cylindrical surface, and therefore there is no tendency or power to cause wear under any variation in the pressure of the air. The mode in which the two eccentrics drive the air valve is by means of a "Gymbal Ring;" that is to say, there is a wrought-iron ring encircling the air valve and attached to it by two pins opposite each other, and the eccentric rods are attached to the ring at two other points at right angles with the first: thus the air valve is perfectly free.

The air cylinder A is 30 in. diameter and 2 ft. 6 in. stroke, and the piston makes 80 strokes per minute. The air piston is packed with hemp packing, and has a ring to screw it down; the screws are so arranged that they can be got at by simply unscrewing small plugs in

the cylinder cover, when a socket spanner can be introduced to screw the ring down. The air passes into the air cylinder beyond the end of the valve, first at one end and then at the other, and is delivered into the hollow part of the valve, from which it escapes through two light copper branch pipes MM, placed opposite each other, and having turned joints fitting turned collars fixed on the valve. The other ends of the pipes rest on a small surface or shelf prepared for them, and on which they slide backwards and forwards about ⅛th inch; these ends of the pipes are curved in the same manner as the other ends, so that the faces are in one plane, and the air main has the faces of its branches surfaced to receive them, as shown in the plan, Fig. 3; thus the air is taken equally from each side of the air valve.

The steam valve H has considerable lap, and is so proportioned as to cut off the steam just after the half stroke and have a very free exhaust.

The boilers are on the Cornish plan, and will be chiefly used with wood as fuel, and the furnaces are made proportionately large for this purpose. The boilers are fed by a donkey engine entirely independent of the blast engines, so that they are complete in themselves, and there is no fear of getting short of water whilst the blast engines stand for "tapping," at which time indeed the boiler should always be fed, if only to keep the steam down a little.

The engines having to be transported some distance up the country, a limit of weight was given, viz., 1 ton for any one part of the engine; and in accordance with this limitation the total weight of a pair of these engines is only 11 tons as compared with 25 tons, the weight of an ordinary blast engine of equal power; and the weight of the heaviest single piece of an ordinary engine is 4½ tons as compared with 1 ton, the weight of the heaviest piece in the new engines. It is therefore evident that the engine can be moved with the greatest facility, and the first pair put to work here for trial simply stood on some balks of timber, and a few small bolts through the bed plates were sufficient to hold them and cause them to work quite steadily; whereas for the ordinary engine a strong building with massive foundations has to be erected.

The method by which a high speed for blast engines has been attained is simply that of moving the air valves for the air, having of course very large valves and passages, instead of letting the air itself move the valves. This arrangement, which was introduced by Mr. Slate to this Institution at the Meeting in July, 1850, at once prevents all blow and jar in the working, provided that the lap and lead of the valve are properly proportioned, and allows of the piston being driven at a high velocity, and consequently its diameter may be reduced and its stroke shortened. This mode of working, combined with the fact of two engines working together as a pair with their cranks at right angles, causes such uniformity in the flow of the blast that no regulator of any kind is needed ; indeed the variation is hardly perceptible in a mercury gauge placed on a very short length of main, whereas the variation on the ordinary plan is very considerable, as shown by the indications in the diagram Fig. 7, taken from an ordinary engine, which may be compared with Fig. 8, taken from the pair of small engines. The pair of engines are arranged to blow 3600 cubic ft. per minute, and are speeded to 80 revolutions per minute, which with 2 ft. 6 in. stroke makes 400 feet per minute, and this they do with the greatest ease and efficiency, owing to the exact manner in which the lap and lead and area of passages, &c., are proportioned ; but the author does not wish it to be supposed that he recommends a higher speed, or at all events a much higher speed, for although we have the example of locomotive engines before us every day working at higher speeds, we also know something of the cost of repairs of locomotives working at high speeds, and it is evident that what an iron master wants is a good serviceable engine that will blow steadily on day and night without repairs and stoppages; in addition to these first requisites there are two other advantages which it is certain are attained by this construction of blast engine, namely, first, great regularity of pressure in the blast, and secondly, greatly reduced first cost of engine and of foundations.

The CHAIRMAN said the engines appeared remarkably compact and small for blowing a furnace, and the uniformity of pressure

obtained by them would be an important advantage. There had been a variety of plans advocated for obtaining a blast suitable to the different requirements of the cupola and the blast furnace; and he remembered that at a recent meeting of the British Association the subject had been discussed, and it had been proposed to use the fan for the blast furnace. He understood that there was a furnace near Chesterfield blown by a fan, but he did not know the particulars of its application.

Mr. SAMUEL LLOYD, jun., believed the great difficulty in using the fan for blowing a blast furnace was to get pressure enough for that purpose, and he understood it had been found impracticable to obtain sufficient pressure of blast from the fan to force air enough into the furnace.

The CHAIRMAN observed that it had been argued on the other hand in favour of the fan, that the operations of the blast furnace depended on the quantity of air delivered into the furnace, rather than upon the pressure at which it was delivered, and this view of the question was, he believed, more generally entertained now than previously, but he had not heard the results of the practical trial of the fan for blast furnaces. He mentioned that a number of blowing machines of different constructions were to be seen at the French Exhibition, showing a great amount of skill and ingenuity; in one of them, the general plan of the machine was much the same as that described in the paper, having an upright cylinder like that shown in the drawing, with a very large flat slide valve working on each side, for the admission and discharge of the air.

Mr. COWPER observed that there was a great practical advantage in the engines described in the paper, from the air valve having no side pressure whatever upon it, as it was a circular valve entirely surrounding the blast cylinder, and consequently was perfectly in balance; and being guided very steadily, by fitting the cylinder at top and bottom, its motion was very smooth, and the wear upon it would be very slight.

Mr. SAMUEL LLOYD. jun., enquired whether the small engines were to be worked with high-pressure or low-pressure steam; in the use of high-pressure blowing engines he had known some difficulty to be

experienced in keeping up a regular blast, owing to the steam pressure being occasionally let down in the night; but a low-pressure engine was not liable to that objection. In the present case of a pair of engines blowing together, one might be worked high-pressure and the other condensing with the same steam, and saving a large proportion of the fuel.

Mr. Cowper replied that the engines had been designed specially for lightness, to meet the peculiarity of the situation for which they were intended, and they had therefore been made non-condensing, cutting off at half stroke, with 50 lbs. steam; but wherever the circumstances admitted of it, he would certainly make high-pressure expansive and condensing engines, so that great economy of fuel would be obtained.

Mr. Samuel Lloyd, jun., remarked that in the case of a single blowing engine the use of a fly-wheel was objected to, as it was then found that the blast was less steady than without the fly-wheel.

Mr. Cowper observed that this must necessarily be the case with a single engine, as the fly-wheel, by making the crank shaft revolve uniformly, caused the motion of the piston to be faster at the middle than at the ends of the stroke; but in the ordinary single engines without a fly-wheel, the motion of the piston was regulated by the resistance of the air, and consequently it remained much more uniform throughout the stroke, causing less fluctuation in the supply of air to the main. A fly-wheel was only applicable when two blowing engines were coupled at right angles to one another, but even then the full advantage of the engines being coupled could not be obtained except by a quick-stroke small engine, such as those described in the paper, where the intervals between the successive discharges of air into the main became so small (amounting to less than a quarter of a second) that no appreciable fluctuation of pressure was produced, although the ordinary regulator or reservoir was entirely dispensed with.

The Chairman observed that this regularity of the blast was a great advantage, and gave an important superiority over the ordinary engines; the same advantage would apply still more completely to the fan blast, if it were found capable of producing sufficient pressure, and he should be glad to know the exact particulars of its application to blowing furnaces.

Mr. Samuel Lloyd, jun., remarked that one difficulty in applying the fan to blowing furnaces would arise from the circumstance, that it was sometimes requisite to employ a higher pressure and smaller tuyeres for a time, in order to clear the furnace when it had got out of order; this could be readily effected with blowing cylinders by increasing the steam pressure when required for that purpose.

Mr. Cowper said that a different treatment was requisite for blowing a blast furnace and for a cupola; for blowing a cupola experience had led him to prefer the fan to a cylinder blowing engine; he was aware that a heavier pressure had been advocated for the cupola, but he had found a large quantity of air blown through 10 inch tuyeres better for that purpose than a higher pressure with smaller tuyeres; but for blowing a blast furnace, he did not think the fan would give pressure enough to force air into the centre of the furnace at all. He remembered that a plan had been suggested by Mr. Buckle, at a former meeting of the Institution, for increasing the pressure of the fan blast, by using two or three fans, one blowing into the other, making them all push together, so as to increase the pressure successively, the last one only communicating with the furnace.

Mr. Sampson Lloyd remarked that the great improvement effected in the last few years in the quantity of iron obtained from blast furnaces was mainly attributable to the increased quantity of air blown into them: a few years ago, 40 tons of iron per week was the general yield of a furnace, but this was gradually increased up to 80 and 100 tons, and now 150 to 200 tons per week might be obtained from a single furnace, which was as much as was given by four or five furnaces formerly. He thought it would be impossible to force in the supply of air necessary to obtain this quantity of iron by means of the fan, and he understood it had been given up at the furnaces near Chesterfield that had been referred to.

Mr. Clift enquired what was the power of the pair of blowing engines described in the paper, and the quantity of air they would deliver.

Mr. Cowper replied that they were capable of working up to 34 indicated horse-power each, and delivering together 3600 cubic feet of air per minute, at a pressure of 4 lbs. per square inch.

Mr. CLIFT remarked that it had been proposed to use Jones's Gas Exhauster as a blowing engine, using four of them together, working one into another, in order to get sufficient power; he was not aware that they had been so used in this country, but he believed they were employed to a considerable extent in Sweden, where they were driven by water. This machine was very simple and portable in construction, and he had found it work very satisfactorily in discharging gas; from an experiment that had been made with the exhauster, it appeared that a steam engine of 5 nominal horse-power would force 80,000 cubic feet per hour of coal gas, or about 1300 feet per minute.

Mr. COWPER said that he had obtained a pressure of 10 to 15 inches of water, or about ½ lb. per square inch, with a large fan blowing a cupola with two 10 inch tuyeres; but that 7½ inches (or about ¼ lb. per square inch) was what he had generally adopted for cupolas and smiths' fires.

Mr. W. A. ADAMS observed that he had heard of a fan at Messrs. Cubitt's works, in London, running, he believed, at 2000 revolutions per minute, by which a considerably higher pressure than usual was obtained. A great pressure might be obtained by using three such fans combined, the one fan blowing into the aperture of the other; this plan had been tried by Mr. F. J. Bramwell, and found to answer, the pressure indicated by the last fan being nearly three times that of each separate fan.

Mr. HENRY MAUDSLAY said he had not seen the fan at Messrs. Cubitt's, but understood that a pressure of 16 inches of water was obtained with it; it was a Lloyd's silent fan, 3 feet diameter, and worked quite silently.

The CHAIRMAN observed that Schiele's fan, which was much used in Manchester, was also a noiseless fan; it was worked at a very high speed, making 2000 to 3000 revolutions per minute.

He proposed a vote of thanks to Mr. Cowper for his paper, which was passed.

The following Paper, by Mr. W. Bridges Adams, of London, was then read :—

ON AN IMPROVED SPRING AND AXLE BOX FOR RAILWAY CARRIAGES.

In springs serving as an elastic support various qualities are required for the different purposes. First, they must yield through a sufficient space, to absorb the momentum so gradually as to prevent shocks from being felt, and the space must be proportioned to the shock. Secondly, they should work with the minimum of friction between their parts. Thirdly, if used for varying loads, they should possess the property of equal yield under the light and the heavy load ; an empty waggon should be as easy to ride in as a loaded one.

For springs required to moderate the shocks of buffing and traction in railway trains, a certain amount of friction in the springs is a positive advantage ; it increases the temporary resistance, that is, adds to the strength of the spring, and also moderates the force of the recoil. But for bearing springs, quick action as well as range of movement is essential, and the quicker the speed of the train, the more important it becomes that the action should be rapid.

There are many modes of using steel in carriage springs ; the simplest is the double lever form. In this form of spring the width of plate is limited only by convenience ; the thickness must be limited by the power of equal hardening and tempering in the first place, and next by the convenience of length ; up to a certain point the thickness of the steel may be increased with the length, and the power will be increased, but the yield through space may be made as great with a short thin spring as with a long thick one, though with lessened power. As the power is limited by the limit of the thickness of the plates, lamination or the multiplication of plates one on the other becomes necessary, and this is the commonest form of spring. Whether in single or multiplied plates, it is a direct action spring.

Indirect action springs exist of various kinds, in which the space or yield of the steel is multiplied by leverage other than that of the steel. The bow spring is one example, in which the pressure on

the ends of a slightly arching bow is multiplied three times by levers. This is the most highly elastic spring known, the friction being confined to axis movements, but the cost of the framework of levers is greater than that of the steel.

For the purpose of simple arrangement the laminated lever spring offers the greatest advantages. It is an elastic lever if rightly formed. As a bearing spring it supports the framework of the carriage at different points. As a buffing spring it affords a facility for swivelling on the centre to adjust an equal pressure on the buffer heads, whether on curves or on straight lines of way. But the form and make of the spring may vary, and the elasticity may be impeded, or developed at the wrong part; and in the case of bearing springs the action may be very hard with a light load, while the heavy load tends to break the spring.

The ordinary form of laminated spring, as in Figs. 1 and 2, Plate 30, is a curved line of greater or less radius; in some the curvature has been so great that the bearing points are almost rigid struts, and the steel will scarcely spring at all, and if loaded sufficiently the spring will bend or break over the axle box at the centre.

A form of spring like Fig. 3 has been used formerly, the shape of which is a double inflected curve. The tendency of this form is to a double action in curvature, and breakage where the curvature changes, and a liability when overloaded to set, as in Fig. 4.

The object to be aimed at is to make the spring so strong over the butt or centre that it cannot yield there, and to make the form such as to ensure its yielding sufficiently with a light load, and with an increasing capacity for supporting the load when it is heavy.

In the improved spring, the subject of the present paper, which the writer has adopted for this object, the plates are made in an angle shape, as shown in Figs. 5 to 9, Plate 30, and the specimens exhibited, being formed in two straight or nearly straight lines, rising from the centre, instead of the usual curve. The spring is therefore very firm at the centre in the direction of the strain, whilst the taper points on the contrary are disposed to yield equally and easily, forming as they descend two gradually increasing curves, as shown in Fig. 6, diminishing the actual span of the spring, and consequently diminishing the leverage and increasing the power of resistance.

In the construction of the ordinary laminated springs with flat or slightly curved centres, it is necessary to resort to some method of keeping the several plates central and parallel. This is done either by a bolt passing through the whole of the plates in the centre, or by forming them with a series of studs by indenting the plates at the centre, and clipping the whole together. Either method tends to weaken the plates at the centre, and to break them if the fastenings get loose. To keep the plates parallel, the ends are indented to form studs which work in elongated slots in the plate below, as shown in the plan, Fig. 2, one plate keeping another parallel. But in the mode of ordinary work, these are very inefficient, and if the plates are not well fitted they work askew.

In the improved spring the centres of the plates are all creased to exactly the same angle, as shown in Fig. 7, and thus lie one within another without any tendency to curve lengthwise, each one lying in the valley below it. A clip, or a pair of coupling plates with bolts outside, shown in section in Fig. 8, holds all the plates together, and the angle form retains them so firmly that all slots and studs at the extremities of the plates can be dispensed with.

In the ordinary spring the ends of the plates are tapered, as in the plan, Fig. 2. Originally they were tapered in thickness, but the late Mr. Chapman tried, and successfully, the experiment of tapering in width for private carriages. The length of taper he used was four times the width of the plates. When introduced on railways the desire to save steel gradually reduced the taper to one width, and sometimes to half a width. It has even been proposed to carry the saving of steel to the uttermost, by cutting one plate out of the other with a one-sided taper; but the writer is not aware that this plan was ever adopted, and it is evident that it would tend to push the plates sideways.

In experimenting with the improved spring, the writer found that tapering in thickness caused considerable friction between the plates, by the ends binding against the hollows of the curves, and the tapering in width caused an irregular action. The method was therefore tried of simply cutting the plates off square, as shown in the plan, Fig. 9, slightly rounding the upper edge. This was found to give the most perfect elastic action, and without any waste of steel.

In making ordinary springs it is customary to make the top or back plate of a given curvature, and to increase the curvature of every succeeding plate, afterwards compressing the whole together and fastening by the central bolt or clip. This plan renders the springs uncertain as to strength, and the hammering or setting, denting the surface of the plates, is very apt to cause fractures.

In the improved springs the plates are all creased to the same angle by a pressing machine, and any plate will fit any other plate without any setting up. They can therefore be kept in duplicate, and in case of breakage a common labourer can apply a new plate, without needing a smith and spring fire. Thus the improved spring wastes no steel, has no holes, no slots or studs, and no taper; it is nearly machine-made, and therefore more skilful workmen can be afforded for hardening and tempering; no files or expensive tools are required; and extra plates may be applied for greater loads by merely lengthening the bolts at the centre, and the springs may be made either with rolled eyes or plain ends as usual.

The action of this spring may be reversed, as shown in Figs. 10 and 11, by placing the short plates in the hollow side, suspending the ends, and carrying the load in the centre.

The central angle may be either a sharp angle or a slight curve, but the sharp angle is preferable. If the curve be used more care will be required in fitting, as it is evident that the sharp angle will, in case of slight inaccuracy, hold the plates firmest: any angle may be used which will keep the plates central by the pressure without studs or bolts.

The springs are applied in the axle boxes so that the hoop or clip lies in a hollow, as shown in Fig. 12, Plate 31, and no other fastening is required. This is very important, as, when the axle box is bolted to the spring, it is by inaccuracy frequently strained from its proper bed on the journal, and heating ensues, and continues till the bearing is worn down to a fit.

The axle box preferred by the writer is shown in Figs. 12 to 15, Plate 31, and the sample exhibited. It is a single casting A, with a thick wooden bottom B which is bolted in when placed on the journal. There is a grease or oil chamber C with feed-holes above the journal, communicating by a large opening D, at the front of the axle box, with

the grease or oil chamber below. The box is rendered tight so as to contain a well of oil or grease, by two half cast metal collars E at the back, the upper one supporting a spring that draws up the lower to clip the axle, which is formed to a conical shape at the back of the shoulder, so that the pressure of the spring always forces the collar down the cone and against the back of the box, but with a facility for a slight elastic yielding in case of any irregular resistance. It is obvious that as the collar slides up the cone, there will be a slight inaccuracy in the fit, but the wear will take place at the joint, where it is not important, and the lower half collar up to a sufficient height will always press close to the axle. In front of the box, and passing down the opening D inside, is a gun-metal slide F, adapted for four changes, against which the end of the journal works, so that there is no need for any fit against the shoulder and collar, and the end wear of the brass is entirely prevented.

This box accordingly fulfils the several conditions required; namely, keeping the lower part of the axle in a bath of grease; saving the grease from waste; saving end wear of the brasses and oscillation of the carriage; diminishing the risk of heating by efficient ventilation; saving breakage of bottom castings; in case of heating, affording the facility of filling the box with water from above; saving the need of lifting the boxes, by allowing access below; and by reason of the absence of fastening, and the elasticity of the spring under all circumstances, diminishing the chance of heating.

The improved springs have been in use on the South Western Railway nearly six months, from the 5th of May last, and they have given every satisfaction. From an experiment made upon four springs on September 25th, it was found that two of them, after a pressure of 3 tons had been applied, set $\frac{1}{8}$th of an inch, and the other two resumed their original shape. The experiment was made after they had been in use upwards of four months, and had run a distance of 2434 miles under a heavy covered goods waggon; and previous to this working, they were also tested with the same weights without the least set being produced.

In point of first cost they are cheaper than the ordinary spring, inasmuch as a saving of 40 lbs. weight per set of four springs is

effected, for a spring with 8 plates on the new plan is quite equal to a spring with 10 plates of the usual construction, the weight being 72 to 73 lbs. in the new, as against 84 lbs. in the old. The new springs are not so susceptible of derangement as the ordinary spring, and are more elastic and adapt themselves better to the loads; they are also less liable to break, and altogether form a simple and compact arrangement.

Mr. Adams exhibited several specimens of the improved spring, one of which was taken to pieces, and put together again; and also a specimen of the axle-box.

The Chairman observed that the liability of the ordinary springs to a permanent set after wear was a great objection to them, and the comparative freedom from set of the new springs was an important consideration; also the simplicity of their form and make would be a practical recommendation. He enquired how long the new springs had been at work.

Mr. Adams replied that they had been at work nearly six months; the great advantage in the improved spring was the ease with which repairs could be effected, consequent upon the simplicity of its construction. No smithing was required, and the plates were heated only once, and creased and tempered at the same time, without requiring a second heating, the only process in making the spring that involved any skill or experience being the tempering of the plates. There was no danger of any lateral displacement of the plates, although they were not provided with studs and slots, the clip and the angle to which they were creased holding them securely against any derangement.

Mr. Ramsbottom remarked that in the ordinary spring the steel was weakened at the centre by the central bolt hole, which was a defect; and the new spring was superior in having no central bolt hole. He enquired whether any of the plates had been found to break across the centre, in consequence of the creasing.

Mr. Adams answered that no damage had been found at present to be caused by the creasing, but the plates might no doubt be injured

if creased too much, so as to crush the metal. In the ordinary spring a greater number of plates were required at the centre to make up for the loss of strength caused by the bolt hole; this added to the weight, and in the new spring, by avoiding the necessity for adding more plates, a saving of more than 40 lbs. per waggon was effected.

Mr. Ramsbottom remarked that it was important in any laminated spring that under a great weight all the plates should be brought into full action throughout their entire length, and this appeared to be effected in the new spring. He enquired whether the action of the shortening leverage was fully realised in practice.

Mr. Adams replied that he had not yet had an opportunity of making practical trial of the best form of the new spring, in which the ends shortened the leverage under a heavy load by gradually curving down; the springs that had at present been tried, had been applied to waggons fitted with scroll irons, and consequently the springs had rolled ends. The shortening leverage would have the effect of increasing the rate of increase of the resistance, as the spring bent. The inverted form of spring that had been described was a convenient arrangement for the back end of a locomotive, where it was sometimes desired to substitute a single transverse spring or a pair for the two trailing springs ordinarily used, on account of the confined space available; in such a case, the above form of spring, requiring but little room for its action, and lying nearly straight between its two extremities, would be particularly eligible for the purpose. The construction of the new spring, in any of its forms, would readily allow of additional plates being inserted, so that its strength could be increased to suit any load it might be required to carry.

The Chairman observed that vulcanized india-rubber springs had been frequently used for the trailing springs of engines, on account of the small space they occupied, and he enquired what results had been obtained from their working.

Mr. Ramsbottom said that he had not tried them for all the springs of an engine, but he found them to answer very satisfactorily

for the trailing wheels; it was important, however, that the india-rubber should not be overloaded.

Mr. ADAMS said that in order to ensure their proper performance, a large quantity of india-rubber must always be employed, and it was then too expensive a material to be much used. The cost of the tackle or attachments also, in the india-rubber springs, was greater than in the case of steel springs, and he thought steel was in the end the cheapest and most eligible material for bearing springs.

The CHAIRMAN remarked that it had been supposed at one time that india-rubber was perfectly elastic; but though highly so, it undoubtedly had its limits, and became rigid if over-strained; some of the india-rubber springs appeared to have failed from that cause.

Mr. ADAMS observed that in steel springs his experience had led him to the conclusion, that in whatever form the steel were disposed, whether the spring were a volute, spiral, flat, disc, bow, or laminated lever, there was always nearly the same quantity of steel required to give the same elastic action under the same load, supposing each to be the best form of its class; if the quantity of steel, and consequently the number of particles to bear the strain, were reduced, the action on each particle would be more severe, and the spring would become liable to set or break.

Mr. RAMSBOTTOM observed that he had been led also to a somewhat similar conclusion as to the weight of steel required being nearly the same for the same work, in whatever form it were arranged.

The CHAIRMAN remarked that in the Report of the Commissioners on Railway Structures, an account was given of experiments made by Capt. James at Portsmouth Dockyard, on the effects of long repeated deflections upon the permanent elasticity of bodies; in some cases the repetitions of strain were carried up as high as 250,000 actions, and it was found that every material, however elastic, became finally deteriorated and failed, differing only in the extent and time of action.

Mr. ADAMS observed that the disc spring had been tried under a continuous deflection involving reaction, and it was found that it would never serve for more than four hours' work before it

broke; the effect of the continued action appeared to be the same as in the spring-beam helves used by steel makers for the tilt hammers; these could not be worked more than four or five hours at a time, and then required six or eight hours' rest before they could be put to work again, when they appeared to have recovered their elasticity.

The CHAIRMAN said that the simple construction of the new spring that had been described, and its comparative cheapness, consequent upon the diminished weight and the ease with which it could be manufactured, were strong recommendations in its favour.

He proposed a vote of thanks to Mr. Adams for his paper, which was passed.

The following paper, by Mr. David Joy, of Worcester, was then read :—

DESCRIPTION OF A SPIRAL COIL PISTON PACKING.

The piston packing, which is the subject of the present paper, was designed by the writer to carry out the principle which appears to him the correct one, for producing steam tightness with the least loss of power from friction and the greatest economy in repairs, namely, by the use of metal in that form in which it will give out the greatest amount of continuous elasticity, that is, by employing a spring acting through a lengthened space with comparatively slight intensity of pressure, instead of the short and rigid spring or series of springs commonly used in packing metallic pistons.

The piston in which this packing is used is shown in Plate 32, Figs. 1, 2, and 3, and consists of a simple block, into which the rod is screwed and pinned. The periphery of the piston being turned to $\frac{1}{16}$th inch less diameter than the cylinder, a recess is cut in it with a $\frac{1}{2}$ inch tool set at $\frac{1}{2}$ inch pitch, making 3 inches more than 2 revolutions, as shown in Fig. 2.

The packing is formed out of a cast-iron or brass ring, Fig. 4, $\frac{5}{8}$ inch thick and $\frac{3}{4}$ inch larger in diameter than the cylinder. The ring is turned and bored, and being placed on a mandrill, a spiral groove is cut

in it with an $\frac{1}{8}$ inch tool, set at $\frac{5}{8}$ inch pitch, as shown by the dotted lines. This cut being carried through leaves the ring in the form of a spiral coil of $\frac{1}{2}$ inch by $\frac{5}{8}$ inch section, and of about 5 full revolutions. A portion of this spiral is cut off, equal to 2 revolutions and $\frac{3}{4}$ inch over, as in Fig. 5. This is threaded on to the block piston and pushed down till it drops into the recess, which it exactly fills laterally, as shown in Fig. 3. A sheet iron cramp, Figs. 6 and 7, is placed round the packing, by which it is compressed to the diameter of the piston, which is then placed at the mouth of the cylinder, the ports being protected by small blocks of wood, and the piston is then thrust from the cramp into the cylinder.

The objects aimed at in this modification of packing, are, to avoid friction by obtaining an elasticity as light as possible, yet sufficient to produce perfect contact with the face of the cylinder, to ensure steam tightness, and sufficiently continuous to follow up the effects of wear without the necessity of frequent renewal by resetting. And this the writer finds is best accomplished by using a packing which shall consist of the greatest possible length in proportion to its cross sectional area. No figure meets this requirement so fully as the spiral coil, and the number of coils or length of packing can be increased to any extent that may be found advantageous, the elastic action being always in one continuous length.

As the coil fits throughout its length between the parallel sides of the recess in the piston, its two extremities may recede from each other to any distance that may be found requisite for wearing out the rings without at any time exposing an opening for the passage of steam. The packing under all circumstances fills the recess except at the bottom, where the vacant spaces at the extremities of the ring, left in the uncoiling of the ring by wear, are effectually closed by the piston body sliding in contact with the cylinder, that part of the packing ring being placed at the bottom side of the piston for this purpose. By experiments it has been found that with the 16 inch brass packing with $\frac{1}{2}$ inch elasticity of compression on the diameter, and $\frac{1}{2}$ inch square section of packing, the pressure on 53 square inches of surface of packing was 1·92 lbs. per square inch or 102 lbs. on the whole packing. It took 65 lbs. to move this piston backwards and forwards in the cylinder when disconnected from the rest of the machinery and the glands unpacked,

equal to 0·32 or about ⅓ lb. per square inch on the surface of the piston. The 16 inch cast-iron packing with ⅝ inch elasticity of compression on the diameter, and ½ inch by ⅝ inch section of packing, gave a pressure of 4·41 lbs. per square inch of surface of packing, and took 135 lbs. to move it in the cylinder as above, being 0·67 or about ⅔ lb. per square inch on the piston. This experiment was made immediately after the engine had done her day's work, when the cylinder lids were taken off, and the glands unpacked for the purpose. Previously to unpacking the glands, the steam at 110 lbs. pressure was put on behind the pistons with a most satisfactory result, there being no appreciable leakage of steam past the piston. A similar trial has frequently been made by merely opening the cylinder cocks, and putting steam on behind the piston, when no appreciable blow is observable.

A corresponding experiment was also tried with a 16 inch piston of the ordinary class, having cast-iron V packings, and it was found to require 426 lbs. to draw the piston slowly along the cylinder, when disconnected as in the other experiment, showing more than three times the resistance.

The new packing avoids the frequent necessity for "looking at" the piston, which is so large an item in the expenditure of locomotive running sheds, and this is in a great measure a consequence of the accomplishment of the former object, as the large amount of elasticity resident in the coil will wear out the packing without the necessity of examination for renewing that elasticity by means of resetting the springs, as in ordinary pistons.

This piston has also the advantages of simplicity of construction and freedom from parts liable to get loose and produce breakage of pistons and cylinders. As this packing is used in a block piston it does away with the necessity for lids, nuts, screws, guards, &c., and reduces the piston to its fewest possible number of parts, the rod, the piston, and the split pin to secure the rod to the piston. The packing ring also being always confined in a recess of a cross section exactly equal to its own, if broken can produce no injurious effect, as it must always remain in its place as if whole. The time required for removing the packings is very short, the cylinder lid being

taken off and the cross head cotter knocked out; the piston is then drawn out, when the old packing is threaded off the piston and a new one threaded on in 10 minutes, and the piston replaced. From the long enduring elasticity of the coils they are expected to last without examination at least 15,000 miles, the only need for examination being for the purpose of cleaning. There has not yet been time actually to wear out a ring, but as data upon which to form an approximate opinion, the ring marked No. 2, which is exhibited, has run more than 10,000 miles, and when taken out did not blow.

The new packing is also attended with economy in original cost, as the expense of piston and packing shows a considerable reduction on those generally in use.

A piston fitted with the improved packing was exhibited, and also specimens of the packing rings, which had been some time in use, and showed but a small amount of wear.

Mr. Joy observed that his main object had been to obtain so simple a packing that it should not depend upon the enginemen at all, merely requiring fitting in the repairing shop. The packing rings which he had first tried had been found too slight, being only $\frac{3}{8}$ths inch square, and the subsequent rings had been made stronger, of $\frac{1}{2}$ inch by $\frac{5}{8}$ inch section for a 16 inch cylinder.

The Chairman enquired how many engines were at work with the pistons having the new packing.

Mr. Joy replied that two passenger engines with 16 inch cylinders were running with them, and they would be tried in a few days in a goods engine with 17 inch cylinders; in these engines the packing rings were of cast-iron.

The Chairman remarked that the general appearance of the piston was similar to that of Mr. Ramsbottom's piston, and the diminished friction owing to the light pressure of the coil corresponded with that given by the packing rings in Mr. Ramsbottom's piston.

Mr. Ramsbottom said that he had at first tried a spiral coil in separate grooves, but he had since abandoned that plan in favour of single detached rings. The results that had been stated of the dimin-

ished friction caused by the spiral packing confirmed his own experience of the advantage of a light pressure of the piston packing upon the cylinder.

Mr. Cowper asked in what respect the spiral packing described in the paper differed from the old spiral coil proposed formerly in Jessop's piston, where the coils of the packing ring extended the whole depth of the piston.

Mr. Joy explained that the difference in that piston consisted in the spiral coil being fitted in between two edges parallel to the faces of the piston, and to which the line of the spiral made an inclined plane, the ends of the coil being tapered down to fit these edges, and consequently as the spiral packing uncoiled in wear it became loose sideways, not filling the groove in the piston any longer in consequence of the inclined ends moving off each other and diminishing the total thickness of packing; but in his piston the groove was a spiral corresponding to the packing ring, the edges of the groove being parallel to the coil, and consequently the packing ring remained equally tight sideways when it uncoiled during wear. There was also too much friction between the coils, when the packing took many turns round the piston, and he found that a little more than two turns gave the best action, and was quite tight enough.

Mr. Cowper enquired how the steam was prevented from blowing past the packing at the ends of the coil.

Mr. Joy replied that this was effected only by placing that side of the piston lowest, so that the body of the piston was then in contact with the cylinder, and no steam could pass. In one instance, however, the piston had been put in by mistake the wrong way up, so that the joint was at the top, but no perceptible loss of steam had been detected in working, the piston body being a sufficiently near fit to the cylinder to prevent any material leakage.

The Chairman asked how long the cast-iron packing rings had lasted before they were worn out.

Mr. Joy answered that he could not say how long they would last, as there had not been time yet to wear a coil out; the ring would have to be worn down $\frac{3}{8}$ths inch all round, before it was entirely worn out; the present wear had amounted to only $\frac{1}{8}$th inch, after the rings had run more than 10,000 miles.

The Secretary observed that he had had an opportunity of seeing the pistons with the spiral packing in work, and had found them to be very steam tight, when tried as had been mentioned in the paper.

The Chairman then proposed a vote of thanks to Mr. Joy for his paper, which was passed.

The Chairman then observed that he had been engaged for the last two or three months as a Juror at the Paris Exhibition, where he had found some very beautiful and well-constructed machinery, displaying a great amount of ingenuity and a high degree of attainment in mechanical skill. England had hitherto always taken the lead in mechanical improvement, and the mechanical engineers of this country ought to endeavour to maintain the advanced position they at present occupied. He advised all the members who were able to do so to take an opportunity of visiting the Exhibition and acquainting themselves with the various mechanical improvements that were collected there.

He announced that the next meeting of the Institution would be a Special Meeting in Manchester.

The Meeting then terminated.

After the Meeting, Mr. S. Thornton, of Birmingham, exhibited a powerful Hydraulic Lifting Jack, capable of raising a load of 50 tons by the power of a single man; the ram being 8 inches diameter with an 8 inch stroke, and the pump $\frac{3}{4}$ inch diameter; the whole apparatus was arranged in a compact cast-iron box, weighing about $2\frac{1}{2}$ cwt. altogether.

Mr. G. M. Miller, of Dublin, also exhibited a specimen of an improved Axle-box, used upon the Great Southern and Western Railway of Ireland.

PROCEEDINGS.

DECEMBER 19, 1855.

The SPECIAL GENERAL MEETING of the Members was held in the Lecture Theatre of the Royal Institution, Mosley Street, Manchester, on Wednesday, December 19th, 1855; John Ramsbottom, Esq., in the Chair, in the unavoidable absence of the President.

The SECRETARY read the Minutes of the last General Meeting, which were confirmed.

The following Paper, by Mr. William Fairbairn, of Manchester, was then read:—

DESCRIPTION OF A NEW CONSTRUCTION OF PUMPING ENGINE.

In mining operations the Cornish Pumping Engine has for many years been considered the most eligible for raising water from great depths. In the district of Cornwall, where coal is not one of the native mineral treasures, and where the fuel has consequently to be imported for the supply of the numerous engines employed for draining the tin and copper mines, economy in the consumption of the fuel has always been an object of great importance. Owing to the high price of the imported coal, and the consequently large item that it forms in the annual charges for steam-power, greater attention has been paid to the construction and working of the engines, which has resulted in superior economy; and the Cornish mine-owners have lost no opportunity of affording to the engineer every facility for improvements in the engines and boilers, and at the same time every inducement to those in charge of their manage-

ment to promote their economical working. The encouragement offered by rewards and premiums has given to the Cornish engine its high character for economy in the consumption of coal; and though in other districts, where coal is cheap and abundant, the same necessity for stringent measures to ensure carefulness does not exist, this can be no justification for wasteful expenditure, and neglect of applying the proper means to attain that economy, with which the whole of the steam-power in the country ought to be worked. A knowledge of what has been advantageously accomplished in one district is a motive for its introduction into another, and the writer, being convinced of the superior management prevalent in Cornwall, has always advocated the more general adoption of this important system.

When water has to be raised from great depths by steam-power, there appears to be no better method of doing so than to use the Cornish engine working expansively, employing the engine to raise the plungers and pump-rods, the weight of which, as they descend, forces the water up to the surface or next level. This has been for many years the practice in Cornwall, and has been almost invariably accomplished by a powerful engine with its main working beam placed above the cylinder. For such a position, the lever-wall, &c., supporting the beam, is required to be a mass of solid stonework of considerable height, to resist the shocks to which it is subjected by the sudden descent of the load upon the spring-beams, and which are at times so great in a large engine as to shake the masonry to its foundations. In the engine described in the present paper, this objection is avoided, and the expense of high buildings and massive masonry is saved, by substituting for the single main working beam above the cylinder, two beams placed below the cylinder, one on each side of the engine; resting upon a platform level with the ground, and in the present instance below the mouth of the pit. The advantage of this construction is, that the whole strain at the bearings of the beams, instead of acting upon the raised tower of the lever-wall, is brought direct upon the solid ground, thereby saving the expense of the masonry above the ground. In case the engine should miss a stroke from an accident in the pit, the

shock is received upon a massive oak transverse spring-beam, which passes under the cylinder and rests upon the foundations of the engine-house on each side. A corresponding spring-beam is fixed in the pit to receive the fall of the pump-rods, whenever they happen to pass beyond the limits of the stroke in their descent. This modification in the arrangement has the advantage of making the foundations sustain the weight and shocks of the engine direct, and causes a great saving in the original cost.

The principle of the engine itself presents no material difference from the ordinary construction, and the arrangement is compact, simple, and effective; the engine is worked with double-beat valves, and is so arranged as to cut off the steam at any part of the stroke.

A number of engines on the same plan are now at work, some of them of great power, with 70 to 80 inch cylinders, and they have given complete satisfaction, by their steady, convenient, and economical working.

The engine shown in Plates 33, 34, and 35, was erected by the writer in 1851, at the colliery of F. P. D. Astley, Esq., at Dukinfield; it is a single-acting high-pressure expansive and condensing engine, of about 160 horse power effective, employed to drain a coal-pit of large extent. The depth from which the water is raised is at present rather more than 500 yards, but the extreme depth to which it is intended to work will be about 700 yards, when the lower bed of coal is reached.

Fig. 1, Plate 33, shows a longitudinal section of the engine.

Fig. 2, Plate 34, is a transverse section of the engine, and Fig. 3 a section of the valves.

Fig. 4, Plate 35, is a general elevation of the engine to a smaller scale.

Fig. 5 is a general plan, showing the pumping and winding engines with the boilers and the pit, in their relative positions.

The two beams AA are carried upon the same frame or bed-plate BB as the steam cylinder C, and each is bolted down to a block of masonry at the level of the floor. The cylinder is 70 ins. diameter, and 8 feet stroke; the piston-rod is connected to the beams by a

wrought-iron cross-head and cast-iron side rods, as in the ordinary marine engine, a similar parallel motion being used, which in this case is carried by two parallel girders DD fixed in the walls of the engine-house, and bolted to the flange of the cylinder. E is the oak spring-beam, 22 inches square, extending transversely under the cylinder, and carried at the ends by the foundations of the building. The ends of the engine-beams strike directly upon the spring-beam, with the intervention only of a block of timber placed upon the spring-beam, with a thickness of india-rubber as a packing to soften the blow. A similar provision is made at the opposite end of the engine-beams, to prevent the pump-rods descending too far.

The valves are all on the double-beat construction; the steam-valve F is 16½ inches diameter in the seat, and the equilibrium and eduction valves G and H are 18½ inches diameter, their motion being regulated by the cataract I, in the usual manner of the Cornish engines.

The condenser K and air-pump L are placed in a well below the floor on the opposite side of the centre of the beam; the air-pump is 35 inches diameter and 4 feet stroke.

The outer extremities of the beams AA overhang the pit at M, where they are attached to the pump-rods by means of a parallel motion N, Figs. 3 and 4; the second pair of beams OO forming the parallel motion are fixed one on each side of the pit in recesses, working clear of the pit; they carry at their outer ends a large counterbalance weight P, consisting of a box filled with cast-iron weights, to counterpoise a portion of the weight of the pump-rods, leaving only sufficient unbalanced weight for raising the water in the pumps.

The pumps consist of six sets of plunger pumps, commencing with one bucket pump at the bottom; they are shown in succession in Figs. 6 to 12, Plate 36.

The main pump-rod R has a stroke of 8 feet, and is 15 inches square at the top, being attached by a wrought-iron strap to the cross-head of the parallel motion N.

The first four pumps, Figs. 6, 7, 8, and 9, are all of the same

size, with 12 inch plungers, and 12 inch rising main; the pump-rod R diminishes in size from 15 inches square at top, to 11 inches square at the fourth pump down, and 8 inches square at the two lowest plunger pumps, and each of the plungers is attached to it by a timber block and iron straps.

The two lowest plunger pumps, Figs. 10 and 11, are of similar construction and dimensions, except that they are smaller in diameter, the plungers being only 8 inches diameter, and the rising main 8 inches; the difference is made in consequence of a portion of the water entering from a higher level of the workings into the cistern of the fourth pump, Fig. 9.

The bottom pump, Fig. 12, is a bucket and plunger pump, raising the water at both strokes of the pump-rod. The barrel of the pump is 8 inches diameter, and the pump-rod 5 inches square, being half the area of the barrel, so that half the water is raised at each stroke.

Figs. 13 and 14 show the detailed construction of the top pump, drawn to a larger scale. The suction and delivery valves are leather flap valves, with two semicircular openings.

Each pump has the same lift, and raises the water 200 feet, delivering it into the cistern from which the succeeding pump draws. The engine makes about 13 strokes per minute, and the quantity of water raised is consequently 500 gallons per minute, being equivalent to about 160 horse power effective.

The pumps and pit work have been arranged with a view to saving room, and at the same time affording facility for repairs, and convenient access to the valves and buckets of each of the sets into which the pumps are divided. The entire space occupied by the six sets of plunger pumps, and one bucket pump, is only about one-fifth of the area of the shaft, which is 12 feet in diameter; and the shaft not only contains the pumps to a depth of 1500 feet, but also has space enough for the ascent and descent of two sets of boxes, each box containing about 8 cwt. of coal. A description of the large Winding Engine, used to raise the coal in this pit, was laid before the Institution at a former meeting, (see Proceedings Inst. M. E.,

December, 1853); and the position of the engine is shown at S in the general plan, Fig. 5.

The CHAIRMAN observed that the arrangement appeared more judicious than the old plan of the beam at top, as the engine was more compact, and the principal strains and shocks were brought directly to the level of the ground, without the intervention of walls or columns.

Mr. BEYER had seen the engine at work, and thought it one of the finest pumping engines he had seen; it was well executed, and appeared to work well; the engine and pumps were conveniently arranged for access, and the fixing of the beams was solid and simple; he thought the arrangement would be found to be generally preferable.

Mr. SIEMENS enquired what was the extent of expansion in the engine, and the pressure of steam employed; he thought that the principle of expansion was not yet carried to its utmost practicable limits, although these limits were approached: but science had already pointed out the way which would lead without fail to a further great improvement of the steam engine.

Mr. NEALE replied that the steam pressure was about 15 lbs. per inch, and it was cut off at about 1-5th of the stroke; there were 5 or 6 boilers in use, cylindrical double-flue boilers, 7 feet diameter, and 27 feet long, with flat ends and gusset stays, the internal flues being 2 feet 8 inches diameter.

The CHAIRMAN then proposed a vote of thanks to Mr. Fairbairn for his communication, which was passed.

The following Paper, by Mr. William G. Craig, of Manchester, was then read:—

ON AN IMPROVED AXLE BOX AND SPRING FITTINGS FOR RAILWAY CARRIAGES.

From the numerous defects in the construction of the Axle boxes and Spring fittings in general use for railway carriages, much attention has been directed to their improvement.

In the Axle boxes, the principal defect is in the seats for the gun-metal bearings; these are arranged in various ways, but all involving expensive fitting of the bearings into their places, to secure them from getting loose, notwithstanding which they frequently turn on one side, as represented at A, in Fig. 1, Plate 37, and are also liable to drop out of their places entirely, and remain in the bottom of the axle box, causing the journal to come in contact with the cast-iron box, which is soon destroyed, as in the example shown in Fig. 2, which is one out of a large number of similar cases. In many instances the journals are completely twisted off. These occurrences necessarily cause great delays to trains, and require the carriage or waggon to be sent into the workshops for repair. In order to prevent the brasses from coming out of their places, they are cast with deep sides, and not unfrequently rivetted to the axle boxes; but the consequence of this is that when the brass warms, its sides grip the journal, and soon cause the bearing to heat.

Another defect in axle boxes is in the mode of lubricating, which tends to create the evil of hot journals, before the remedy can act. This arises from the thickness of the metal that forms the seat of the bearing and bottom of the grease chamber, which in many cases amounts, together with the bearing, to two inches thickness above the journal, and must be heated through by friction, before the grease can be brought down to lubricate the bearing. In numerous instances, from the metal becoming overheated, the grease is rendered fluid, and runs out and is wasted.

Another disadvantage is that, from the carelessness of workmen, the holes for the passage of the grease through the axle box and bearing are often not made to correspond, and the flow of grease to the journal is consequently obstructed; it is also difficult to clean out such holes when required, to do which properly involves a considerable loss of time, and the evil arising from not frequently picking them out is a total stoppage of the lubricating material, causing cut journals.

Another difficulty is that of getting the grease to the back of the grease chamber to lubricate the inner collar; this is now done by the greaser pressing back the grease with his knife, when time

admits, and is generally only imperfectly accomplished whilst the carriages are temporarily stopped at a station.

Further, the number of parts belonging to the axle boxes now in general use, namely, bolts, nuts, leather packing, &c., all involve expensive fitting, and are subject to frequent displacement.

In the axle box grease covers, again, there is a constant rattling noise with all iron covers that are without springs, and they often require repair from being made slight, and the hinges being strained; and with the sliding arrangement, the covers get lost in transit, and grit and other foreign matter then mixes with the grease, and produces hot axles, either by stopping up the lubricating holes, or by coming in contact with the journal. An objection also to iron covers is, that during the summer months they quickly conduct the sun's heat to the grease, and cause it to run to waste.

In the Spring fittings, all arrangements are defective where bolts, nuts, or screwed spring clips are used for fixing the spring to the axle box, as these are not found sufficient to retain the spring in position in ordinary concussions, entailing the frequent loss of bolts and nuts, and at times of the whole spring. It is also objectionable for the ends of the spring to bear against fixed shoes fastened to the sole-bars, since the spring on elongating causes the ends to rub hard upon the shoe, which wears a recess in it, and also wears the top plate of the spring; the result is that a shoulder is formed upon the shoe, and in many instances the spring cuts the body of the shoe entirely away, and bears upon the wood, as represented at BB, Fig. 1, which is an exact copy of one of the many so found on the Manchester, Sheffield, and Lincolnshire Railway; in all such cases the spring is prevented from acting beyond the limit of the shoulder formed on the shoe. Amongst the methods adopted to remedy this defect, the spring ends have been softened and bent downwards to fit the shoe, and the top plate of the spring has been thickened to allow for wear; the former plan has been abandoned as inefficient, and the latter, which is now generally in use, is subject to the objection before named.

The failures of the axle boxes, bearings, grease covers, and spring fittings described above, which are occurring daily upon all railways,

involve a serious item in the working expenses, and from his experience of the causes producing them, the writer has been led to adopt the improved construction of axle box and spring fittings, the subject of the present paper.

Axle Box.—The improved axle box is cast in one piece to avoid all expensive fitting of leather packing, bolts, nuts, &c.; the mode of lubricating through the axle box seat by means of holes is dispensed with, and the lubrication is effected direct through the gun-metal bearing. All expensive fitting of the bearing is avoided, by casting an oblong hole in the axle box seat, to receive a projection C, Figs. 3 and 4, cast upon the top of the bearing; these can then be put together as they come from the foundry, a slight looseness being of little consequence, since the projecting piece completely prevents the possibility of the bearing turning on one side, as at A, Fig. 1. This axle box is also much lighter than the ordinary construction, and all bolts and nuts are dispensed with, excepting the two bolts that fasten the under keep.

The projection cast on the top of the bearing is made hollow, and passing through the oblong hole in the seat of the axle box into the grease-chamber above, supports either the cap of the axle box, as in Fig. 3, or the under side of the spring itself, as in Fig. 4; by this means is ensured not only the impossibility of the brass turning, but also the perfect lubrication of the journal through the large aperture in the projection, which brings the grease in direct communication with the journal, so that a very small increase of temperature is sufficient to cause the perfect lubrication of the journal. In this case the cast-iron of the axle box is never required to get hot in order to soften the grease, that being one of the chief causes of hot journals. A further advantage obtained by the projecting piece on the top of the bearing is that the brass may be made of a shallow form, so that it will never require its sides to be reduced to prevent them from clipping the journal.

There have been many ingenious contrivances introduced, intended to prevent hot boxes, and to save grease, by the employment of a leather valve, or a similar contrivance, placed at the back

of the axle box, to prevent the escape of grease or the admission of grit; but the writer's observations have led him to the opinion, that the evil of hot boxes does not arise from grit or sand entering from behind, but mainly from the defects in the bearings that have been referred to. True economy is to ensure perfect lubrication, and the projecting hollow piece on the top of the brass that has been described, has an advantage in this respect, in affording a facility to the greasers at stations for pressing the grease down upon the top of the journal.

Grease Covers.—In the grease covers the writer has adopted two plans to suit different forms of springs. In the first, shown in Fig. 3, the cover D clasps the top of the axle box, and prevents the admission of grit, dust, &c., which cannot be too carefully excluded from the top of the box; it is cast with an oblong recess upon it, extending upwards, which receives the grease above the level of the grease-chamber, and is fitted with a wooden plug or plunger E, secured by a chain to the waggon, in place of the ordinary iron cover or slide; the grease being thus introduced above the level of the grease-chamber ensures the perfect lubrication of the whole bearing, being forced by the pressure of the plunger into the recesses at the back of the brass. With the ordinary axle boxes, the ends of the journals nearest the wheels are frequently found quite dry and cut, in consequence, as is generally supposed, of grit or dust being admitted between the boss of the wheel and the axle box; but this the writer considers mainly arises from the difficulty of securing a constant flow of grease through the inner grease-hole of the axle box and brass, the greaser being unable to reach to keep that orifice clear.

There have now been 60 sets of the improved axle boxes working in the most efficient manner for the last eight months, over a long extent of railway in Lincolnshire, where the ballast is of an extremely light and sandy nature; showing that the true remedy for hot journals is their more efficient lubrication, and a ready means by which the greaser can without trouble ensure this. The wooden plug or plunger E, being a non-conductor, serves to protect the grease from the effect of the sun's heat during the summer.

The second modification of improved grease-cover, shown in Figs. 4 and 5, is combined with an improved spring fixing; a wrought-iron plate is employed about $\frac{3}{16}$ths inch thick, and of sufficient size to project over the axle box top about $\frac{1}{2}$ inch all round; an opening is made in the plate to admit the grease, and two other openings to receive the ends of the spring-clip F, to which the plate is cottered. On the top of the plate is fixed a piece of wood, about 1 inch thick, on which is screwed an oblong casting, similar to the oblong recess in Fig. 3, having a wooden plug E to fit the opening; the advantage of this arrangement is that this portion of the grease-cover can be replaced when broken, without having occasion to lift the waggon.

Spring Fixing.—The improved spring fixing consists of a simple and cheap contrivance in combination with the axle box; a piece of iron F, $\frac{1}{2}$ inch thick, and the same width as the spring, is simply bent over the spring to form a clip, allowing the ends to project to form cotter-holes, and to fit into the cover of the grease-chamber. Two cotters fasten the clip tightly to the spring, and are cut so as to correspond with the length of the grease-chamber, by which means they are prevented from getting loose. The cotters form the two sides of an oblong recess on the under side of the cover, and receive between them the projecting hollow piece C on the top of the brass, as in Fig. 4. A piece of wood or india-rubber is inserted between the under side of the spring and the top of the projection C, to form a cushion for the spring.

A modification of the improved spring fixing for application to existing stock is made by fixing two pieces of iron, about 2 inches wide, and the length of the width of the spring, and about $\frac{3}{8}$ths inch thick, by means of the bolt through the centre of the spring; on each side of these pieces is fixed a welded hoop of iron, 1 inch by $\frac{1}{2}$ inch, (as a support for the centre of the spring, in addition to the ordinary small rivet passing through the spring,) and a corresponding recess is made on the cast-iron cover of the grease-chamber.

Spring Fittings.—The fittings at the ends of the springs are

improved by making the shoes GG, Figs. 6 and 7, to slide on a metal bed H, about $\frac{3}{4}$ inch thick, and of sufficient length to allow of the play of the spring with the sliding shoes attached.

The plate H is fixed on the under side of the sole-bar, materially strengthening the waggon, and the sliding shoes have grooved sides to secure them to the plate. The spring is connected to the shoe by a bolt passing through the side cheeks of the shoe and the spring eye, the object being to retain the spring attached to the waggon, when the journals require examination, saving considerable expense and time in lifting. The writer has been enabled to reduce the contract price for the lifting of waggons 25 per cent. on all those waggons fitted with the improved axle boxes and spring fittings; this may at first sight appear an unimportant matter, but assuming each waggon requires lifting twice a year, and that a railway company's stock consists of 10,000 waggons, the saving in this item alone would amount to £500 per annum.

The sliding shoe maintains the perfect action of the spring; its bearing surface is equal to 256 square inches for the whole waggon, which must necessarily reduce the wear and tear of that portion of the waggon, when contrasted with the present mode of spring fixing, where the bearing surface amounts only to 64 square inches; assuming a loaded waggon to weigh 12 tons gross, in the former case the pressure per square inch amounts to 105 lbs., and in the latter to 420 lbs.; the action of the waggon springs is in consequence so easy as to be almost equal to that of a first-class carriage fitted with scroll-irons, if the same length of spring is used in each.

In conclusion it may be mentioned, that during the last six months, out of a stock of 4000 waggons fitted with ordinary axle boxes, on the Manchester, Sheffield, and Lincolnshire Railway, there have been 81 hot journals, 70 brasses destroyed, and 28 journals rendered unfit for use, involving great expense in repairs. A similar return from the East Lancashire Railway, for the last eight months, out of a stock of 1600 waggons, gives a total of 44 hot journals from brasses turning in their seats, 22 brasses destroyed, and 3 journals rendered unfit for use, exclusive of spoiled axle boxes. On the contrary, with the waggons fitted

with the improved axle boxes and spring fixings, there has not been a single instance of a hot axle box, although upwards of sixty sets have been in daily use for the last eight months.

A number of specimens were exhibited of worn and broken shoe-plates, and of damaged journals, and of brasses taken from waggons running on the Manchester, Sheffield, and Lincolnshire Railway; also specimens of the improved spring fittings and axle box, described in the paper.

The CHAIRMAN observed that in the ordinary mode of lubricating railway axles, as the grease employed was only in a soft state, and not fluid, it required to be slightly warmed before it would run down sufficiently to lubricate the journal; and the construction of the bearing brass described in the paper, owing to the projection of a part of its substance into the grease chamber, appeared to have an advantage over the ordinary plan, in producing this effect sooner, and with a smaller rise of temperature in the bearing and the journal.

Mr. NEWALL had made a trial of the new axle box and spring fittings, upon the East Lancashire Railway, and found them very satisfactory; he had had ten sets of them running there during the last four months, and they had proved at present so successful that he intended to try them more extensively; no heating or other trouble had occurred with them, but with the ordinary construction of axle box he had experienced great inconvenience and expense from heated journals, through dirt getting into the grease chambers, and the displacement of the bearing brasses; the concussions of the waggons in shunting were the main cause of the brasses getting displaced. He considered half the expense of current repairs in lifting waggons was occasioned by defective lubrication, and had made trial of several plans for effecting an improvement; but he had certainly not found any so successful as the plan now described. The brasses wanted no fitting in putting them into the axle boxes, and as far as he had tried them, they had proved very satisfactory in lubrication. The mode of

attaching the spring ends by means of the sliding shoes was more durable, and gave a more free action of the spring than the ordinary plan, and also prevented the spring from getting out of place; and a considerable saving of time and expense in lifting was caused by having the springs secured to the waggon frame.

Mr. Beyer had seen both the plans at work, and thought the new brass was an improvement in affording a more immediate contact of the journal with the grease, and means of communicating the heat direct from the journal, instead of requiring it to pass through the thickness of the cast-iron box, as in the ordinary make. The wood cover of the grease chamber appeared to him rather objectionable, as liable to come out of its place in running.

Mr. Jackson suggested that a simple india-rubber spring might be applied if requisite to prevent the covers jumping out.

Mr. Newall had not found them at all liable to come out, and the wood plug had an advantage in squeezing the grease down on to the journal when pushed into its place. The iron covers were objectionable from their looseness and rattling, and they were found to get very hot in the sun, causing the grease to be melted and wasted, which was prevented by the wood covers.

Mr. A. Sinclair said that with the new axle boxes in use on the Manchester, Sheffield, and Lincolnshire Railway, the wood plugs had been found to keep in their places quite securely; they were a little tapered, and fitted tight in the sockets; the plugs first used were made rather longer, but they had subsequently been shortened, as the extra length was found to be unnecessary.

The Chairman said he had not observed the new axle boxes at work, but he had witnessed some experiments that had been made as to the comparative efficiency of the new form and the ordinary form of bearing brass, and the result was decidedly favourable to the greater readiness with which the new brass softened the grease, and lubricated the journal.

Mr. Beyer was also present at the experiments referred to, which were made with two similar journals on an axle revolving at the same time in the two brasses under comparison; and the grease was found to be melted in about ten minutes with the new form of brass, but it

took above twenty minutes with the old one. The temperature of the axle was about twenty degrees higher in the latter case, and the brass became partly cut, but the other one kept in good order. The two brasses were of the same material, and of the same size of grease hole. The axle was driven by a pulley, and at a speed corresponding to about fifty miles an hour speed of a railway carriage.

The CHAIRMAN proposed a vote of thanks to Mr. Craig for his paper, which was passed.

The following Paper, by Mr. Thomas Dunn, of Manchester, was then read:—

DESCRIPTION OF A NEW DUPLICATE RETORT STEAM BOILER.

The difficulties and expenses attending the transit of large Steam Boilers made on the ordinary construction, in consequence of their unwieldy size, led the writer of the present paper to consider the feasibility of forming a boiler in parts, in such a manner that it should possess the advantages of the ordinary large boilers without their disadvantages.

The large boilers in common use weigh in some cases 18 tons, and their bulk is sometimes a greater objection to them than their weight, causing great loss of time and expense. As a practical illustration, some cases may be referred to, that have occurred recently in the writer's experience, and have caused great inconvenience and expense.

A 50 horse power boiler that had to be sent to the neighbourhood of London, measuring 22 ft. long and 6½ ft. diameter, could not be conveyed the whole distance by railway, from want of sufficient clearance under the bridges, and had to be drawn part of the way on the common road, requiring 24 horses, and more at the hilly parts, causing serious expense and delay.

In another case of a pair of boilers, 24 ft. long and 6½ ft. diameter, with a dome 3 ft. high rivetted upon each, the same

cause prevented them from being conveyed by railway, and a similar difficulty occurred on the common road from the arch of a bridge being too low.

In shipping to foreign countries, the great bulk and weight of boilers becomes a very serious objection, and in the case of a 30 horse power boiler, sent by the writer to Canada, 20 ft. long and 5¾ ft. diameter, and weighing about 9 tons, the expense of transit was increased to at least three times the value of the boiler, by the extra expenses attending the shipping and unloading of so large and heavy a mass, and the difficulties of conveyance over bad roads after landing.

From the above examples, and many others that might be cited, it will be apparent that a boiler capable of being readily transported would cause great saving in time and expense of transit. Such a boiler must also satisfy the following requirements:—it must be able to stand a working pressure of not less than 200 lbs. per square inch; and it must be of simple construction, and must admit of being easily repaired.

These conditions the writer believes are fulfilled by the new boiler described in the present paper, which consists of a series of small cylindrical boilers or retorts placed side by side, and connected together by pipes at the extremities, the number of retorts being such that their total capacity shall be equal to that of a single large boiler of ordinary construction.

The new boiler is shown in Figs. 1 to 4, Plate 38.

Fig. 1 is a plan of the boiler.

Fig. 2 is a longitudinal section.

Figs. 3 and 4 are transverse sections.

AA are the cylinders or retorts, made of the best wrought-iron plates, ¼ inch thick, 9 feet long, and 17 inches diameter; the ends are cast-iron hemispherical caps, ¾ inch thick, rivetted upon the cylindrical portion, to which are fixed the cast-iron connections from the steam-chest B, the feed-pipe C, and mud-pipe or blow-off pipe D. The retorts are built into the side walls of the furnace at each end, and supported on a saddle of firebrick in the middle; they are

placed $1\frac{1}{4}$ inch apart, the space between them being closed by a wedge-shaped piece of firebrick, leaving the whole of the lower semicircle exposed to the flame, and half of the upper. The plan represents nine of the retorts arranged side by side and across a double furnace. The flame traverses the bottom of all the retorts, and then passes to the top through the double arch E, returning over the retorts to the front, and thence to the chimney at F. The retorts have thus 3-4ths of their surface exposed direct to the flame, and consequently absorb a great quantity of heat. The cast-iron ends are outside the walls of the furnace, so that they suffer no injury from exposure to the flames; whilst their extra thickness keeps in the heat, and renders them stronger than the other parts of the boiler.

The steam-chest B, the feed-pipe C, and the mud-pipe D, send off branches to each retort, whereby the steam is carried off equally from all, and an equal distribution of the feed water is produced. The feed water is introduced at the opposite end to that at which the steam is taken off, but the mud-pipe is at the same end as the steam-pipe and the opposite end to the feed-pipe, and thus the boilers can be thoroughly cleared of scale or deposit, as often in the day as may be desired, by simply opening one or both of the blow-off cocks, situated at the ends of the mud-pipe. The opposite end of the retort, at which the feed water enters, is cast with two connections, one of which receives the feed-pipe, and the other is closed by a cover plate; by this means, when the boiler is reversed to equalize the wear, the bottom being turned upwards, the feed-pipe connection then becomes the closed one, and the one previously closed now receives the feed-pipe; at the same time, the connections of the steam and mud pipes at the other end of the boiler are also reversed, merely requiring the flange joints to be broken. Each end is provided with a manhole, and thus the boiler can easily be laid clear open from end to end.

In this boiler there is no internal flue, and no part is exposed to a pressure from without, tending to make it collapse, but all the pressure is from within. The nature of the pressure thus renders the boiler safe, in contrast with those having an internal flue, the

danger of which has been experienced in several recent accidents; in one instance, the pressure was 45 lbs. per square inch when the flue collapsed, and in the case of a locomotive boiler, having a return flue 30 inches diameter, made of $\frac{1}{2}$ inch Lowmoor plate, the flue collapsed and blew up the engine when it had not been at work more than a week.

The retort-boiler has no small tubes connected with it, and thus saves the trouble and expense which they occasion, particularly with dirty water or inexperienced attendants; at the same time, there is less tendency to accumulation of deposit, the interior of the retorts being uninterrupted; and in case any dirt should collect, the mud-pipe D gives every facility for cleaning out, and the retorts may be examined at any time by means of the manholes at each end.

The peculiar construction of the boiler prevents the adhesion of incrustation or scale of more than 1-16th inch thickness to the internal surface, as the contraction from the boiler cooling at night loosens the scale, and the formation of the fresh scale forces it off. Upon removing the manhole doors to clean the boiler, the deposit was found in two of the retorts only, the remainder being almost free from deposit of any kind, after 13 weeks' constant working.

The small diameter of the retorts increases their strength, and accordingly a boiler of this description is stronger than a single large boiler of equal power. One of the retorts has been proved by hydraulic pressure up to 300 lbs. per square inch without bursting, being at least three times the ordinary working pressure.

The several parts are all duplicates of one another, so that they can be easily replaced when injured or worn out; or the power of the boiler can be increased, when desired, by adding more retorts; and the plain cylindrical shape of the retorts allows of their being reversed so as to equalize the wear.

The new boiler combines with it abundance of furnace room, allowing the more bulky kinds of fuel to be used, such as brushwood, peat, sawdust, or the cheapest sort of coals, and affording space for the addition of any kind of smoke-burning apparatus that may be desired.

A boiler of the above construction has been at work upwards of ten months at the writer's works, in Manchester, and has given complete satisfaction. It supplies steam at a pressure of 50 lbs. per square inch to two engines, one with a cylinder of 8½ inches by 2 feet stroke, making 60 revolutions per minute, and the other with a cylinder of 7½ inches by 18 inches stroke, making 80 revolutions per minute. The indicated horse power of the two engines together is 17 horse power, the average pressure of steam in the large engine being 28½ lbs. per square inch, and in the small engine 27 lbs. per square inch. The boiler also works a steam rivetting machine, 30 inches diameter, and equal to 7 horse power. This, together with the two engines, gives a total of 24 horse power. The consumption of fuel is 135 lbs. per hour of ordinary furnace coals, or about 5⅝ lbs. per indicated horse power per hour; but the boiler is working at a disadvantage owing to the length of the steam pipes connecting it with the engines; one being 180 feet long and the other 84 feet, and passing through an open yard. Taking into consideration the loss caused by radiation from this extent of surface, it appears that the new boiler is economical and cheap, as it can be made at the same price as an ordinary large boiler of the same power. Also in consequence of the small weight of the separate parts of which it is composed, the heaviest of which does not exceed from 7 cwt. to 8 cwt., it can be shipped or loaded for overland transit at the price of ordinary machinery, with an important saving over the large boilers at present manufactured.

The CHAIRMAN observed that the boiler described in the paper appeared to be designed more particularly with a view to portability and lightness, and those qualities would certainly be of considerable advantage in many cases. From the mode of setting the boilers with a portion of their upper surfaces exposed to the flue, it appeared that the steam would be partially surcharged with heat, and some caution would be requisite to prevent this being carried to any objectionable extent.

Mr. Dunn replied that it was only the return flue, to which the upper surface of the boilers was exposed; the flame first passed under the whole of the retort boilers, acting on the lower half of their surfaces, and then returned over the top of all of them, acting there on half of the upper surface, and leaving one quarter of the entire surface of each protected by the wedge-shaped fire-bricks fitted in between the retorts; he did not think there was any risk of heating the steam too much.

Mr. Siemens thought the steam would certainly be super-heated to some extent by the exposure of the upper portion of the boiler, but this would prove an advantage, as steam in first rising from water was always in a state of transition, containing a portion of water mixed with it, being more or less imperfect as a gas. When this steam was heated, a very rapid rate of expansion took place during the first few degrees, from the whole being transformed into a perfect gas; but the expansion afterwards progressed at a very slow rate, approximating to that of the expansion of air by heat. Super-heated steam gave an important advantage in working expansively, as the steam on entering the cylinder at the beginning of the stroke at a high temperature became partially cooled at once, by the cylinder being only at a mean temperature considerably below the highest; and in this case, with ordinary saturated steam, the consequence of its being cooled was the condensation of a portion of the steam at every stroke, depositing a dew on the sides of the cylinder; but if the steam were super-heated sufficiently, it would not be cooled down to the condensing point, and no water would be formed in the cylinder. The difficulty in practically applying super-heated steam, was the risk of over-heating it, in which case it dried up the lubricating material of the cylinder, and caused the piston to grind. The boiler that had been described, appeared a good plan for accomplishing the object, under safe control.

Mr. T. Forsyth had seen the boiler at work, and was much pleased with it; it was a very strong construction, and the arrangement was particularly convenient for transit; he had had experience on railways of the serious difficulties and delays attending the carriage of large boilers, which Mr. Dunn's arrangement would obviate. He agreed fully in the value of super-heated steam, and thought the circumstance of

the present boiler having worked for eight months at the time he saw it, without any objection being experienced from the steam being overheated, was a good test of the principle having been applied within safe limits.

The CHAIRMAN enquired what difference of water level was found throughout the boiler; and whether any difficulty had been experienced from priming.

Mr. DUNN replied that the water level was about one inch above the centre of each boiler, and very little difference in level was perceived between the two end boilers and the middle one, where water-gauges were fixed. There had not been any difficulty from priming, and he thought the boiler was more free than usual from this objection.

The CHAIRMAN enquired what difference was found in the deposit as compared with the old boiler that had originally supplied the place of the present boiler, and what was the quality of the water used.

Mr. DUNN replied that there was a considerable proportion of earthy matter in the water, and a crust was formed in the old boiler of $\frac{3}{8}$ to $\frac{1}{2}$ inch thickness in the course of four months; but in the new boiler the incrustation never extended beyond the formation of thin scales, less than $\frac{1}{8}$ inch thickness, (specimens of which were exhibited,) which became regularly shelled off by the alternate expansion and contraction, and were mostly blown out at the mud pipe.

Mr. BEYER had seen the boiler, and the feature that struck him most was that there was nothing but internal pressure throughout; he thought it was a step in the right direction, especially for boilers intended for high pressures, where external pressure upon cylindrical flues became particularly unadvisable. As to priming, it must be observed that there was a greater proportion of water surface than usual, which rendered the liability to priming less, by diminishing the violence of ebullition. There was also a separate steam chamber, which would help in separating the water from the steam.

The CHAIRMAN enquired the comparative results in consumption of fuel with the old boiler and the present one, which had been stated to burn $5\frac{1}{2}$ lbs. of coal per horse power per hour.

Mr. DUNN said he was not able to give the comparative consumption of the old boiler with sufficient accuracy to be of service; it was

a cylindrical boiler, with a single flue, but was old and out of order, and the consumption would be above the average.

Mr. Jackson observed, that it was important to have an economical boiler, and some constructions in use were much more expensive in fuel than others.

Mr. Longridge thought a consumption of 5½ lbs. per indicated horse power was rather high, but the engine might perhaps be in fault; some engines in the neighbourhood were working with only 3 lbs. of coal per indicated horse power per hour. He enquired whether the water evaporated per lb. of fuel could be stated, as that was the only correct test of economy in the use of the fuel. In the boiler that had been shown, he thought there would be some risk of over-heating the steam too much, as the brickwork at top might perhaps get red hot; there were certainly advantages in super-heating the steam, if this were not carried too far, but it was very important to avoid any risk of such an occurrence.

Mr. Dunn said he had not had an opportunity at present of correctly measuring the water evaporated; he did not suppose the boiler was quite so economical in fuel as some of the best forms, but thought it would show a good comparison with those in ordinary use; his particular object, however, had been to obtain portability and convenience for repairs and renewal.

Mr. Beyer remarked that the boiler that was at work could not be taken as a test of the evaporative economy of the plan, in consequence of the great extent of steam-pipe and steam-chamber exposed to loss of temperature.

The Chairman moved a vote of thanks to Mr. Dunn for his paper, which was passed.

The following Paper, by Mr. William B. Johnson, of Manchester, was then read:—

DESCRIPTION OF AN IMPROVED HORIZONTAL CONDENSING STEAM ENGINE.

The engine described in the present paper has been especially designed for stationary purposes, and is found to possess the advantages

of simplicity of construction, stability in working, and facility of access to its various parts. The author has superintended the construction of several stationary engines, made according to this arrangement, and their working has proved very successful.

The designing of stationary steam engines is perhaps attended with less difficulty than that of either locomotive or marine steam engines, not being limited, as the latter necessarily are, within certain prescribed bounds, both as to the size and weight.

In most cases the space available for stationary engines is practically unlimited, and their weight, except so far as the first cost is concerned, is of no importance. With such freedom in designing, simplicity of construction, and ready access to the various parts may be studied with considerable advantage, as being two important elements which require much attention, in order to make stationary engines moderate in cost, in the first instance, and convenient in use or working. Simplicity of construction and facility of access to all parts of a stationary engine appear to be more obtainable by the use of the horizontal construction than by any other arrangement; and this circumstance induced the author to direct his attention more especially to the adaptation of this mode of construction to the purposes of a stationary engine.

The engine forming the subject of this paper is shown in the longitudinal and transverse sections, Figs. 1, 2, 3, and 4, Plate 39.

The steam cylinder A is of the ordinary construction, with the exception that the part for securing it to the framing consists of a circular flange B, formed at the end of the cylinder next to the framing; this flange is made to fit against another flange of the same diameter, formed at the end of the framing C, and the cylinder is secured to the framing by means of bolts passing through the flanges.

The framing is composed of one casting; from the end next to the cylinder to the opposite end of the piston-rod guide-bars, the parts CC of the framing are placed under and above the centre line of the piston-rod; the remaining part D, from the piston-rod guide-bars to the crank-shaft bearing, is placed in a line with the centre of the length of the crank-shaft bearing. The framing is strengthened by flanges at its upper and lower edges, the lower flange forming the foot of the framing,

and being secured by holding down bolts to the foundations. In the framing are made the openings required for the piston-rod guides and the crank-shaft bearing; the flange joint B is the only connection that has to be made, in order to secure the cylinder and crank-shaft bearing firmly to each other.

The cylinder slide valve is placed on one side of the cylinder, Fig. 4, and the condenser E below, forming a foot or support for the cylinder, and the exhaust steam enters the condenser by the passage F, the condensing water being injected through a perforated injection pipe. The air pump G is situated below the condenser, forming part of the same casting, and is placed in a horizontal position; the plunger is worked from the piston-rod by means of the levers H, placed one on each side of the framing, and fixed on the same centre pin; the upper ends of the levers are connected by a pair of rods to the piston-rod cross-bar, and the lower ends by a cross-bar and rod to the air pump plunger, giving it a stroke half of that of the steam piston. The air pump valves are both circular metal valves, and move upon a vertical fixed spindle; the lower valve communicates with the condenser by means of passages formed on each side of the air pump in the end of the condenser next to the valves; the upper valve delivers the waste water from the air pump into the hot well, whence it is conveyed away.

The level of the engine-house floor is made to agree with the underside of the condenser or air pump, whereby the centre of the engine and most of its working parts are raised, and are thus placed in the most convenient position for examination, oiling, &c. The air pump plunger can be packed or tightened up without removing any part of the engine. The air pump valves can be taken out and examined by the removal only of the top cover of the valve box. The cylinder piston can be examined by the removal of the cylinder cover at the outer end, and the cylinder slide valve by removing a cover at the same end of the engine. No part of the engine is placed under the engine-house floor, except the water piping, and no part higher than the engineman can reach conveniently.

In engines having cylinders of more than 16 inches diameter, the piston-rod is continued through both ends of the cylinder, and in the stuffing-boxes are placed two long bushes, divided into two halves

horizontally, and as the lower halves wear away by carrying the weight of the piston and rod, they are raised by set pins, so that the piston is kept in its correct line of movement, and prevented from bearing too much on the lower side of the cylinder. This adjustment is effected without removing any part of the engine, except the glands, which are used to determine whether the piston-rod is central with the stuffing-box, and consequently the piston true with the cylinder. The piston-rod guide-bars are permanently fixed to the framing C, parallel with the cylinder. The slide blocks are placed further apart, as they are worn away, by set screws and nuts, which also serve to adjust the position of the piston-rod cross-head to the centre line of the cylinder. The lower nut is first used to adjust the height of the cross-head, the correct position of which is ascertained by moving the piston-rod gland backwards and forwards in the stuffing-box. The upper nut then regulates the position of the upper slide block, to fill up the space between the slide bars suitably for working.

Condensing and non-condensing engines, of from 8 to 70 horse power nominal, have been made according to the arrangement above described; and in some cases, two cylinders, one non-condensing, and the other condensing, have been coupled to one shaft, working on what is usually termed the "compound principle," the cranks being keyed at right angles with each other, one at each end of the shaft.

The indicator diagrams obtained from these compound engines are in general similar to those shown in Fig. 5, Plate 40, the upper being taken from the non-condensing cylinder, and the lower from the condensing cylinder; the latter diagram is shown divided in the centre, and the two halves transposed, for the purpose of showing them in connection with the corresponding portions of the diagram from the non-condensing cylinder. The steam side of the diagram from the non-condensing cylinder is more or less full, according to the extent to which the steam is expanded. The irregular line on the exhaust side of this diagram arises from the cylinders being at right angles with each other. At the point K, the crank of the condensing cylinder is passing the centre, and consequently it is not taking steam from the non-condensing cylinder; the exhaust steam of the non-condensing

cylinder is accordingly slightly compressed a little before and after the point K, but this compression produces a corresponding increase of force acting upon the condensing cylinder at the commencement of its stroke. To avoid as much as possible this compression on the exhaust side of the piston of the non-condensing cylinder, the slide valve of the condensing cylinder has little or no lap on its steam side, as appears by reference to the diagram of the condensing cylinder. The irregularity on the steam side of this diagram is occasioned by the exhaust of the non-condensing cylinder taking place at about the centre of the stroke of the condensing cylinder. Diagrams taken from these compound engines, when working in the ordinary manner, with cranks not at right angles but opposite, or on the same side, are of course free from these irregularities.

The CHAIRMAN observed that the engine appeared a convenient and compact arrangement, for obtaining a condensing engine with economy of space and material, and with a ready access to all the parts. He enquired whether there were any of the engines at work in Manchester.

Mr. JOHNSON replied that there were several of the engines working in the neighbourhood, of various sizes, up to 50 horse power, and a pair were being erected at Messrs. Ormerod's Works, in Manchester, one non-condensing and the other condensing, working together with cranks at right angles. There was a little irregularity in the diagram in that arrangement, which was avoided when the strokes of the two cylinders coincided, but the total loss of power was very small, and there was the advantage of much greater uniformity in the driving power throughout the revolution.

Mr. SIEMENS had seen a somewhat similar arrangement of engine in France, by Farcot, in which there was the addition of a steam-jacket to the cylinder, which he considered was an improvement. The steam-jacket was not sufficiently appreciated at present, and might be used more extensively with decided advantage. M. Farcot had obtained important results in economy by casing both the sides and ends of the cylinder with a steam-jacket, so as to maintain the whole mass of the

cylinder constantly at the highest temperature of the steam, and by that means prevent the condensation of the steam at the commencement of the stroke, which was caused by contact with the colder metal of the cylinder, when the latter was allowed to assume a mean temperature.

Mr. Johnson doubted whether a steam-jacket would prove a practical advantage to a sufficient extent to compensate for the greater complexity; there would also be a greater proportionate loss of heat by radiation from the increased area of external surface of the steam-jacket, and there was a difficulty in maintaining the joints steam tight, from the difference of expansion in large cylinders. An oscillation of temperature undoubtedly took place in the cylinder during the stroke, and this oscillation was of considerable amount in the case of expanding the steam to a high degree; a film of the internal surface of the cylinder being alternately heated and cooled, from the temperature of the high-pressure steam on entering the cylinder being much higher than that of the expanded steam at the end of the stroke; the average temperature of the cylinder being a mean between those two extremes. But he did not see that an advantage would result from adding heat to the cylinder, so as to maintain its temperature throughout the stroke at the highest point, as this heat would only be obtained at the expense of the boiler, all the heat being supplied from that source, so that the additional heat would be merely employed in the cylinder instead of in the boiler. It appeared to him that a complete clothing of the cylinder with felt, or other non-conducting materials, so as to prevent loss of heat by radiation, would answer the purpose as well. When the expansion of the steam was carried to a high degree, he considered the use of a double-cylinder engine, although the total external cylinder surface was greater, was preferable to expanding the whole amount in one cylinder, as the total change of temperature in either cylinder was then limited to half the range, from the expansion taking place in two successive stages.

Mr. Siemens considered that clothing the cylinder to prevent radiation of heat prevented only the smaller portion of the whole loss. The loss that arose from condensation of the steam in the cylin-

der was considerably greater than that from radiation, amounting in some cases to as much as 30 per cent. of the whole power of the steam, or even more, as had been proved in the case of locomotive engines by Mr. D. K. Clark. Although the steam that was condensed in the cylinder at the commencement of the stroke became partially evaporated again in the latter part of the stroke, in consequence of the cylinder being hotter than the steam when the latter was considerably expanded, yet this regeneration of the steam took place when the stroke was completed, and produced only the effect of impeding the formation of a vacuum, without having exerted any useful pressure upon the piston. The only way to obviate this loss was to maintain the cylinder constantly at the highest temperature of the steam, by the provision of a steam-jacket or other means, so as to prevent any condensation taking place in the cylinder.

Mr. Johnson thought the slow conducting power of the cast-iron cylinder had to be taken into account, and supposing the metal an inch thick, there would be only a comparatively thin film of the interior surface that suffered the extreme oscillation of temperature, which would amount to a range of about 150° in the case of 60 lbs. steam being expanded down nearly to a vacuum. A steam-jacket could supply heat only on the outside, and he thought the external heating would not pass through the metal rapidly enough during the time of the stroke, to prevent a considerable alternation of temperature still taking place on the interior surface of the cylinder. He enquired whether the French engine that had been mentioned had a double cylinder, or only a single cylinder, as in the latter case the change of temperature in the cylinder being greater, a steam-jacket would have more effect.

Mr. Siemens replied that it was a single cylinder engine, high-pressure and condensing. He thought it was requisite to take into account the total quantities of heat, and not merely the difference of temperature, as the whole latent heat of the steam was absorbed by the cylinder from the portion that was condensed into water. If the cylinder were hot enough at the beginning of the stroke to prevent condensation of the steam, there remained only the cooling of the cylinder by expansion to be contended with; and then it

must be remembered that dry steam as a perfect gas was a very slow conductor of heat, and consequently could not produce much effect in cooling the surface of the cylinder by contact during expansion.

Mr. Longridge agreed in the value of the steam-jacket, and believed that an important economy was obtained by maintaining the cylinder at the highest temperature of the steam. This might be effected by a casing of heated air instead of a steam-jacket, and that plan had the advantage of not requiring steam-tight joints for the casing, though of course proper precautions were requisite to prevent any risk of over-heating the cylinder. It was employed in Cornwall, and he believed the results were quite satisfactory; the cylinders were heated by a fire below, with flues passing round the cylinder in a spiral direction, and the top cover was also heated, so that the steam never came in contact with anything colder than itself, and was partly super-heated during expansion.

The Chairman remarked that his experience of locomotive engines confirmed the opinion about condensation taking place in exposed cylinders, as there was considerably less priming with inside cylinders than with outside cylinders, the inside cylinders being enclosed in the smoke box, and kept hot in fact by a heated air casing. A considerable economy of steam must result in that case, but he doubted any very material economy resulting from the use of a steam-jacket, as the boiler was then the only supply of heat.

Mr. Peacock had also experienced a greater amount of priming with outside than with inside locomotive cylinders; and believed the difference arose from the outside cylinders being more exposed to cooling, causing a partial condensation of the steam in consequence.

The Chairman proposed a vote of thanks to Mr. Johnson for his paper, which was passed.

The following Paper, by Mr. John Ramsbottom, of Manchester, was then read:—

ON THE CONSTRUCTION OF PACKING RINGS FOR PISTONS.

The writer of the present paper—having invented a few years ago a metallic piston, which was described at a former meeting, (see Proceedings Inst. M. E., 1854, page 70), the packing of which is forced against the working surface of the cylinder by its own elasticity, and owing to its being comparatively slender in cross section, had to be left about 10 per cent. larger in diameter than the block of the piston, in order to give the requisite pressure for preventing the passage of steam—found, that when such packing was made of a circular figure before being compressed, it was invariably worn more rapidly at the joint, and at the part opposite, as at A, B, and C, Fig. 1, Plate 40, than at the intermediate parts D and E. It is very natural that this should be the case, and it has been the practice with many engineers, when using packing rings which are pressed against the cylinder by their own elasticity alone, to make the part C, Fig. 2, opposite the joint, where there is clearly the most strain, stronger than any other, each half being tapered off to the joint; although the writer is not aware that this has been done by any positive rule.

It was taken for granted that the unequal wear above referred to was owing to the pressure against the cylinder being unequal in different parts of the ring, and as the packing rings used by the writer are made of wire or drawn rods, and consequently uniform in thickness, it was found impracticable to ensure this equable pressure by tapering the ring, as in Fig. 2; but as this uniform pressure can be obtained by making the packing ring truly *circular in figure*, but *unequal in thickness*, it occurred to the writer, inasmuch as the rings which he employs are bent and not turned, that the same end might be gained, by conversely making the ring *equal in strength* of material but *unequal in figure*, or in other words that a ring might be made of such a shape, that although uniform in cross section, it would press equally against the working surface of the cylinder all round.

It may be possible to determine geometrically the form of ring required, but the writer preferred to solve the question in a practical manner by the following method :—A ring was first bent truly circular in shape, and of a diameter exactly equal to that of the piston for which it was in-

tended, the ends just touching at the joint, but without pressure; this ring was then placed upon a circular table, Fig. 3, and a number of strings, say 24 in all, were attached at equal distances apart round the circumference, and passed over the same number of small pulleys which were fixed at equal distances round the edge of the table; to these strings were attached equal weights FF, which acting upon equal portions of the circumference of the circular ring, brought it into the shape shown in Fig. 3, GG. The writer then conceived that if a true circle were brought into this shape, when subjected to equal radial forces acting upon equal portions of its circumference, another ring bent to the figure so obtained would conversely be brought to a truly circular shape by the application of equal forces acting in the opposite direction, that is, towards the centre instead of from it; and practice has proved that such a conclusion was correct, for a ring so bent is found to wear equally throughout, and to last much longer than those originally made circular in figure.

In trying these experiments, an important fact has been incidentally discovered, namely, that the force required to keep the packing in contact with the working surface of the cylinder, even at pressures exceeding 100 lbs. per square inch, is much less than is generally supposed. It has been argued that the pressure per square inch on the rubbing surface must be at least equal to the steam pressure which has to be resisted; but so far from this being the case, experiment has led the writer to the conclusion, that as respects the pistons of locomotive engines, this need not exceed 3½ lbs. per square inch of rubbing surface, even when the rings are new and exerting their maximum force; and as these packing rings are practically steam tight until half worn, it follows that the average pressure upon the working surface of the cylinder does not amount to 3 lbs. per square inch. This slight pressure, taken in connection with the small amount of rubbing surface, is sufficient to account for the satisfactory performance of this description of packing.

Mr. Jackson showed the apparatus in operation for ascertaining the correct curve for the piston rings, and exhibited two sets of the rings that had been curved on the improved plan, and had worked

in two pairs of pistons for 12,694 and 10,012 miles respectively, showing a very uniform wear of the rings throughout their length.

Mr. Joy observed that he had found a long and light elasticity was the right plan for the packing of a piston; and the results of his experience confirmed the statement in the paper, as to a very light pressure of the packing rings, not exceeding 3 or 4 lbs. per square inch upon the cylinder surface, being quite sufficient to keep them steam tight if free in their action, and the consequence was a very considerable saving in the friction of the pistons over the ordinary kinds of metallic packing.

The Chairman said his object in the paper had been merely to show the practical way in which a practical difficulty had been surmounted. The result of the improved form of packing rings had been very satisfactory; and about double the mileage was now obtained from the same thickness of rings, compared to the former results, owing to their wear being nearly uniform throughout their whole length.

The Chairman then moved a special vote of thanks, which was passed, to the Council of the Royal Institution, for their kindness and courtesy in granting the use of the Lecture Theatre for the purpose of the Meeting.

A vote of thanks to the Chairman was passed, and the meeting then terminated.

After the meeting some working models were exhibited, by Mr. David Chadwick, of Manchester, of two water meters, and of a rotary steam engine, working on a similar principle, having a flexible cylinder, with transverse rollers fixed round the periphery of a wheel.

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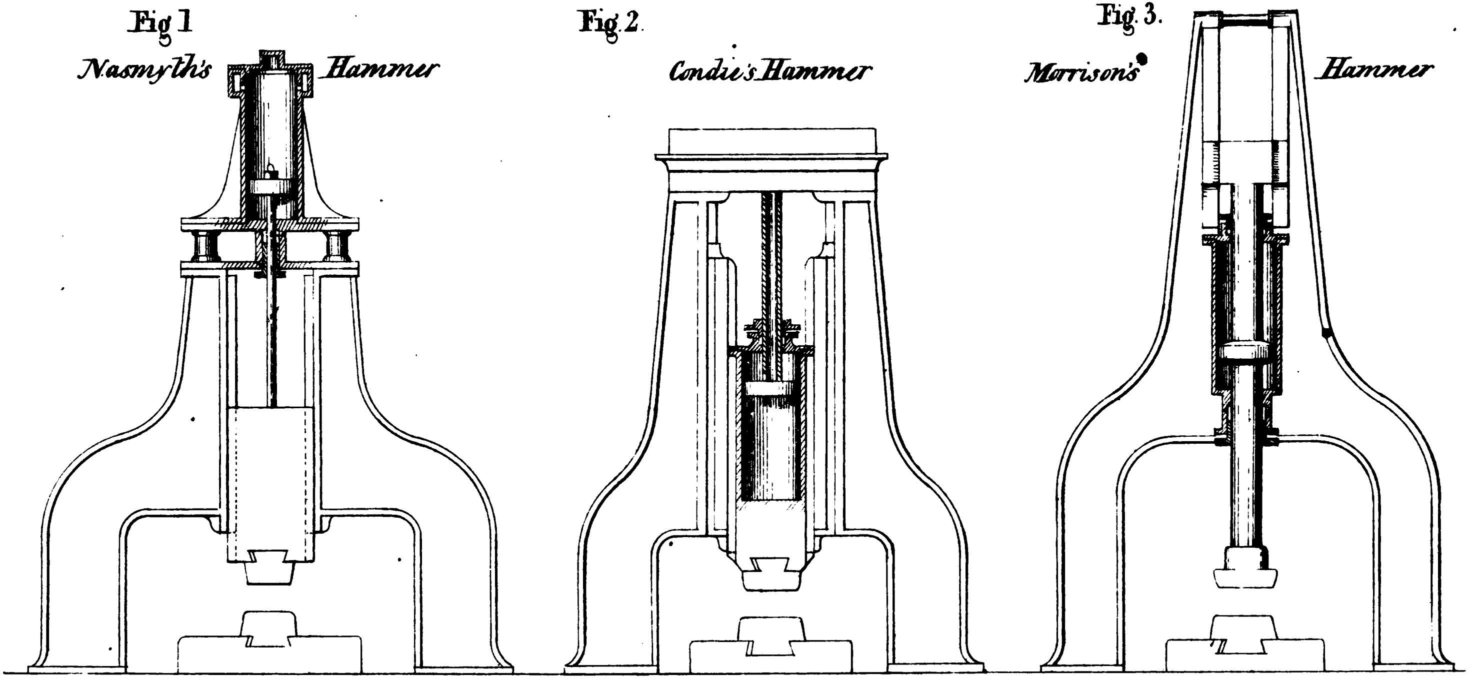
Plate 1

STEAM HAMMER

Fig 1 Nasmyth's Hammer — Fig. 2 Condie's Hammer — Fig. 3 Morrison's Hammer



Scale 1/64th 0 1 2 3 4 5 6 7 8 9 10 11 12 Feet

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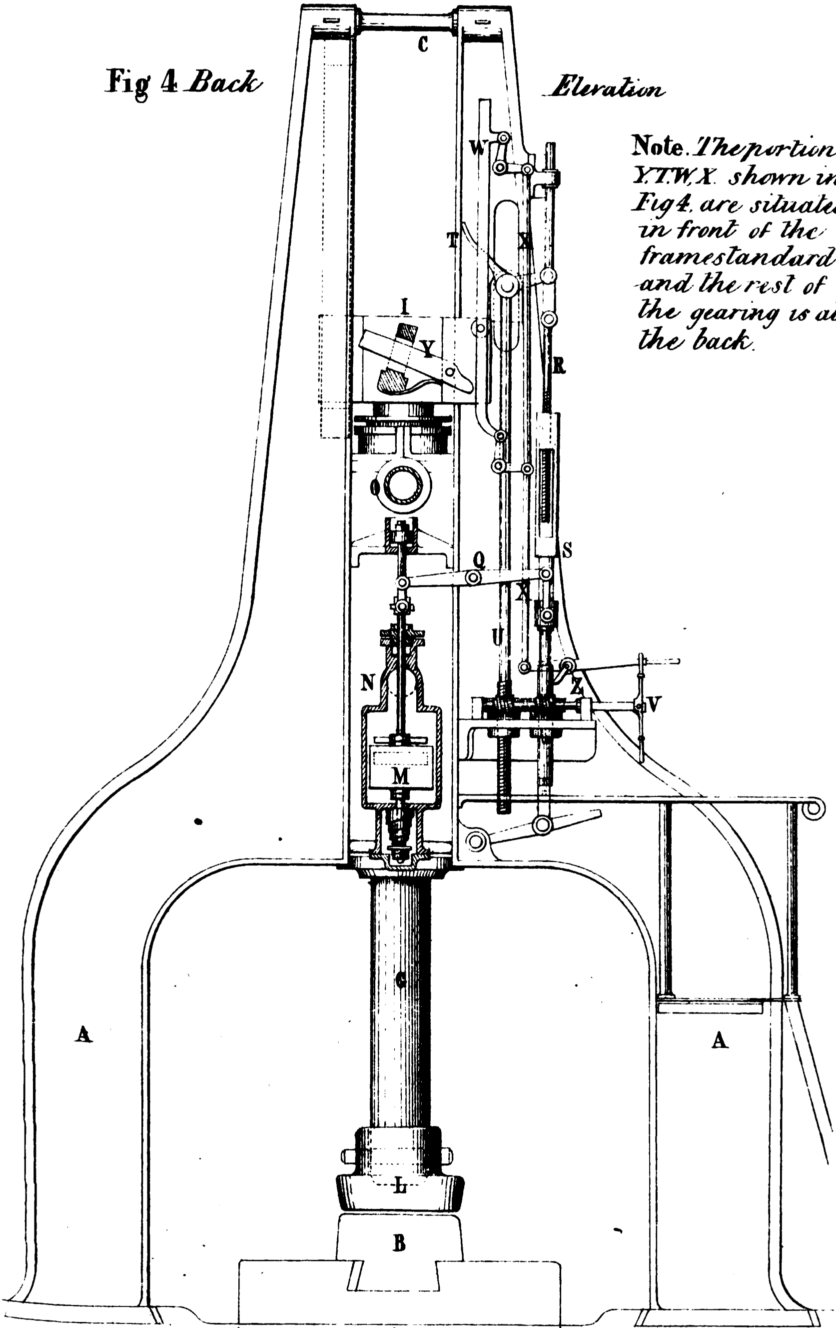
Fig 4 *Back Elevation*



Note. *The portions Y.T.W.X. shown in Fig 4. are situated in front of the framestandard and the rest of the gearing is at the back.*

Scale 1/32nd 0 1 2 3 4 5 6 *Feet*

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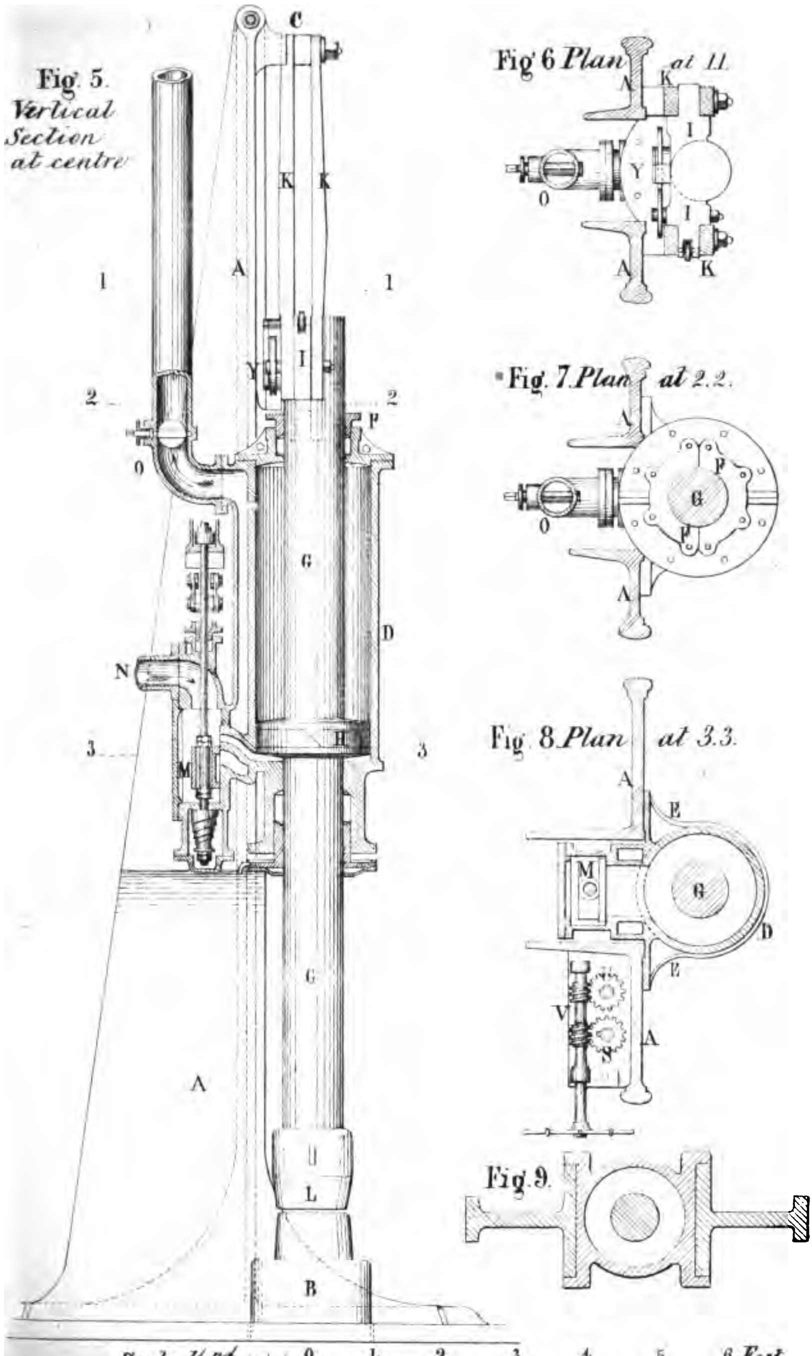
IMPROVED STEAM HAMMER

Plate 3.



COMPOUND METALLIC RODS.

Fig. 1.

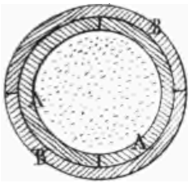


Fig. 3.

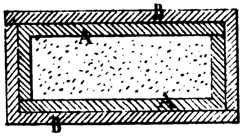
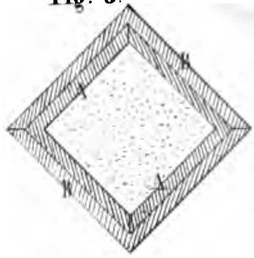


Fig. 5.



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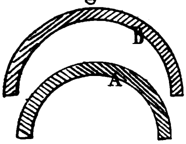
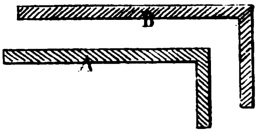


Fig. 4.



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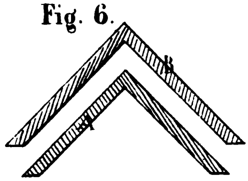


Fig. 7.

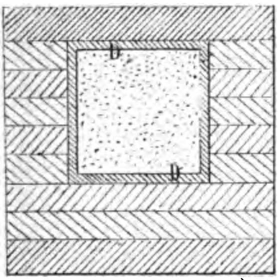
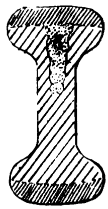


Fig. 8.



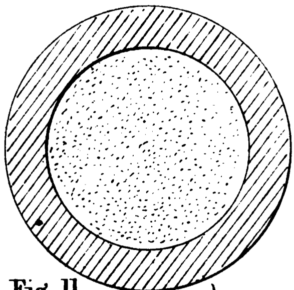


Fig. 11.

Fig. 12.

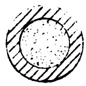


Fig. 9.

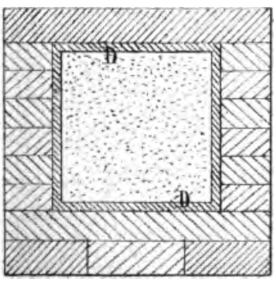
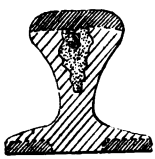


Fig. 10.



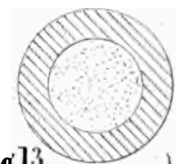
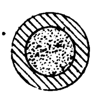


Fig. 13.

Fig. 14.



IMPROVED SAFETY VALVE.

Fig. 1. *Elevation of Single Valve*

Fig. 2 *Transverse Section at CC*

Fig. 3. *Plan.*

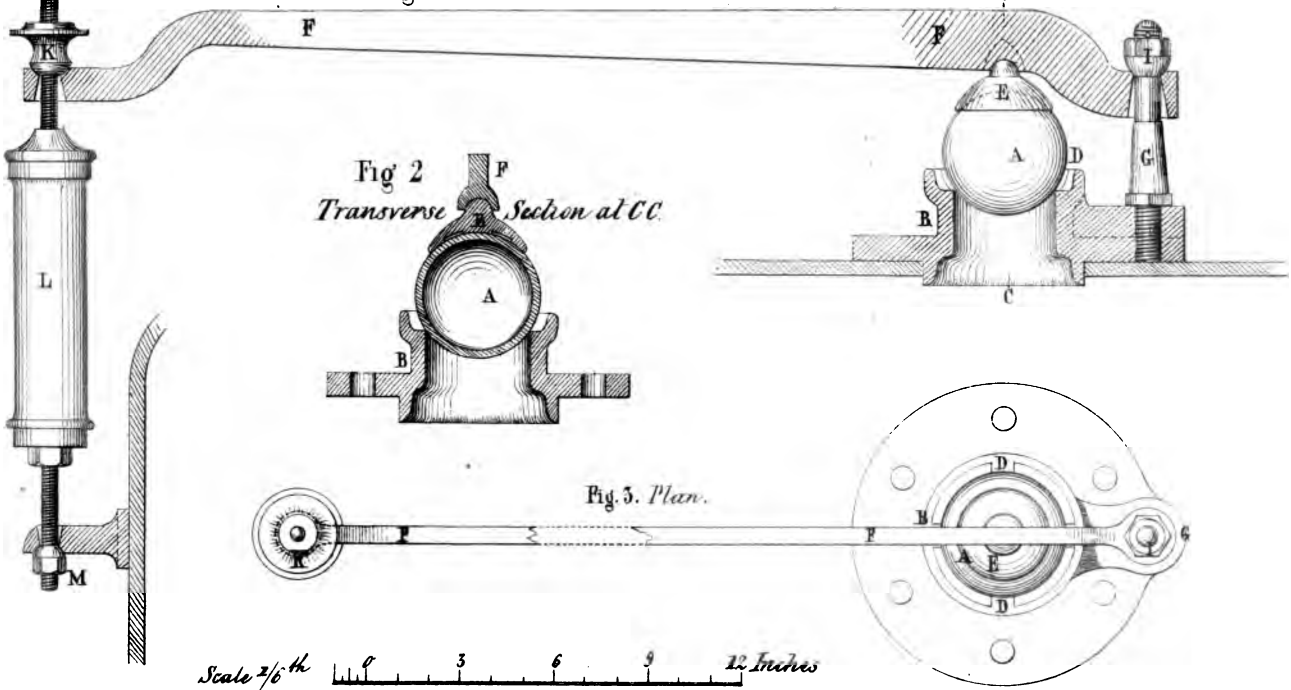


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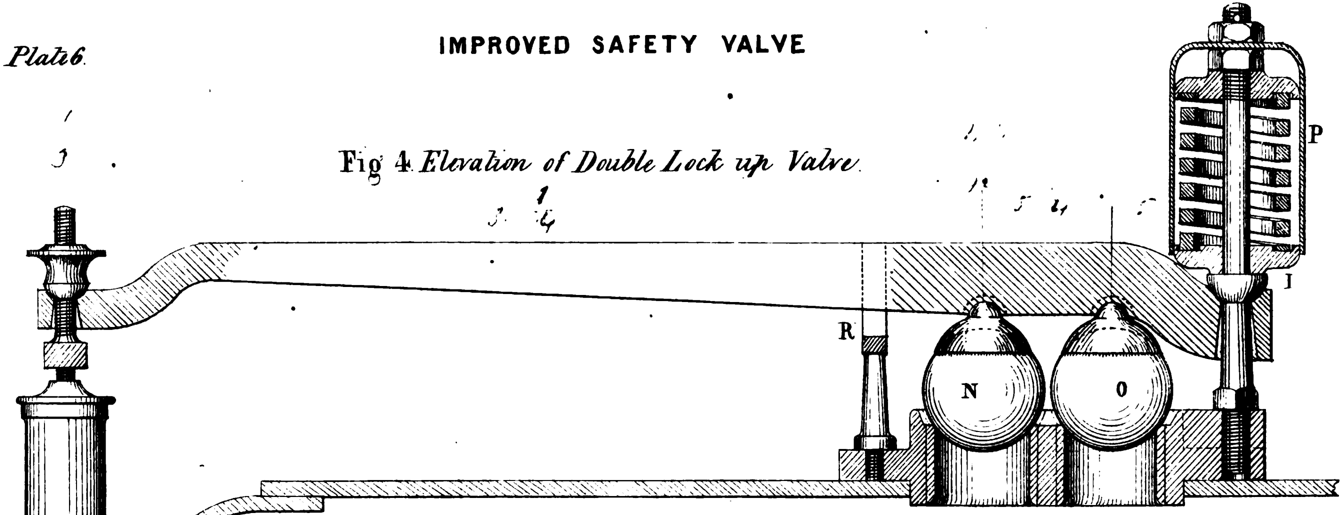
Plate 6.

IMPROVED SAFETY VALVE

Fig 4. *Elevation of Double Lock up Valve*



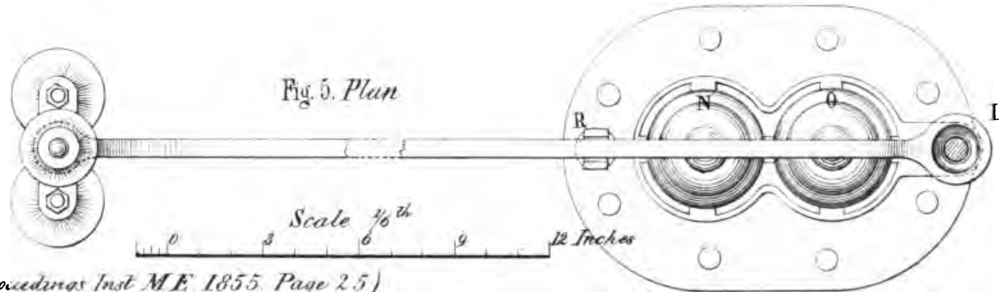


Fig. 5. *Plan*

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IMPROVED SAFETY VALVE

Fig 4. Elevation of Double Lock up Valve

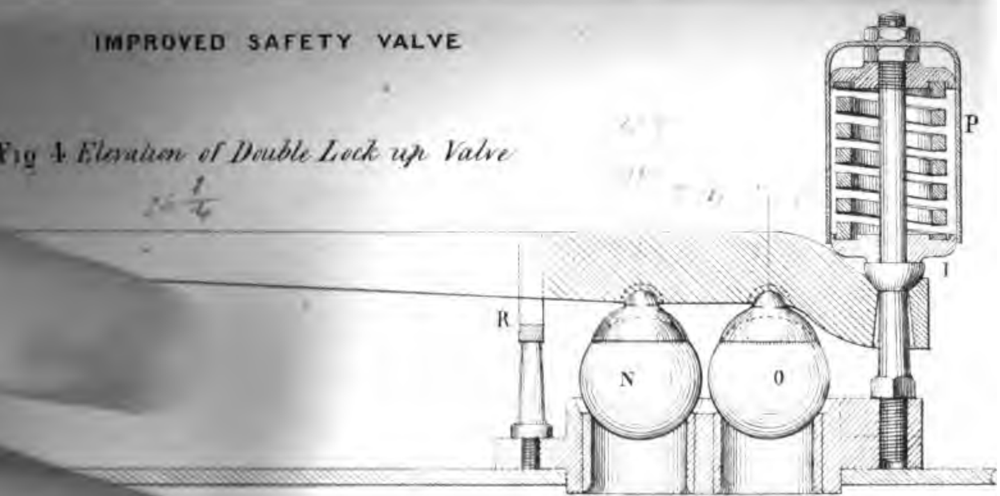
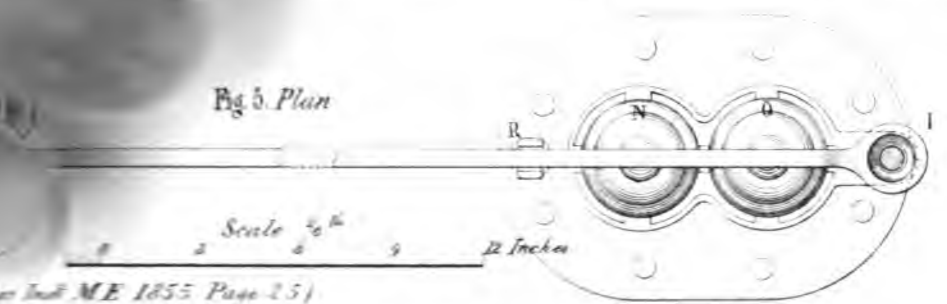


Fig 5. Plan



Scale

12 Inches

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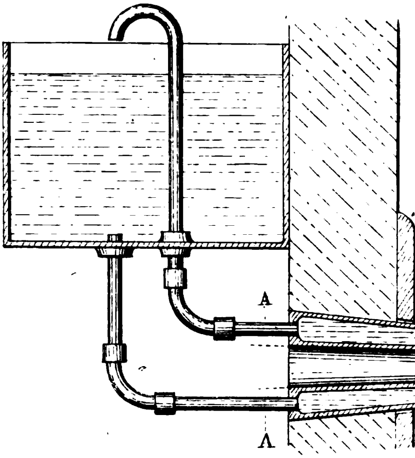

Fig 1.
Ordinary Water Tuyere

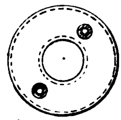

Fig. 2.
Section at AA

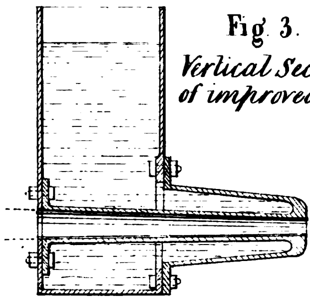

Fig. 3.
Vertical Section of improved Tuyere

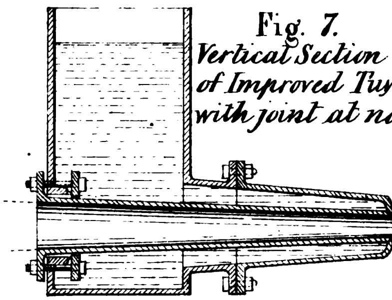

Fig. 7.
Vertical Section of Improved Tuyere with joint at nozzle

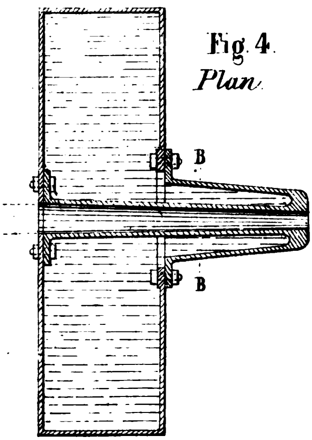

Fig. 4.
Plan

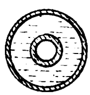

Fig. 5.
Section at BB

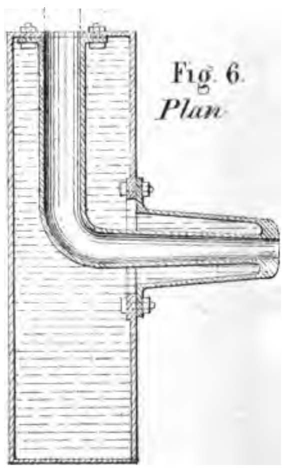

Fig. 6.
Plan

Scale 1/16th 0 1 2 *feet*

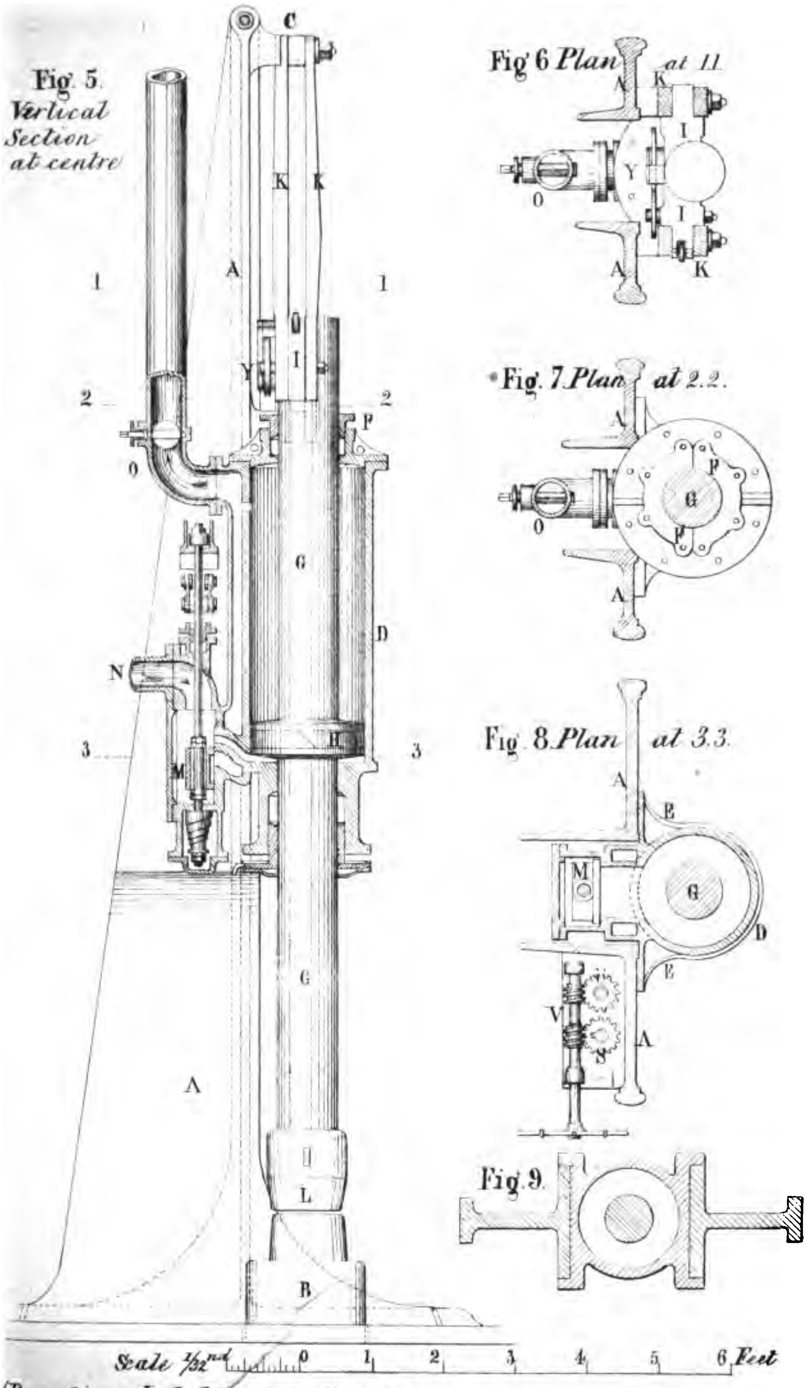

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Plate 5.

IMPROVED SAFETY VALVE.

Fig. 1. *Elevation of Single Valve*

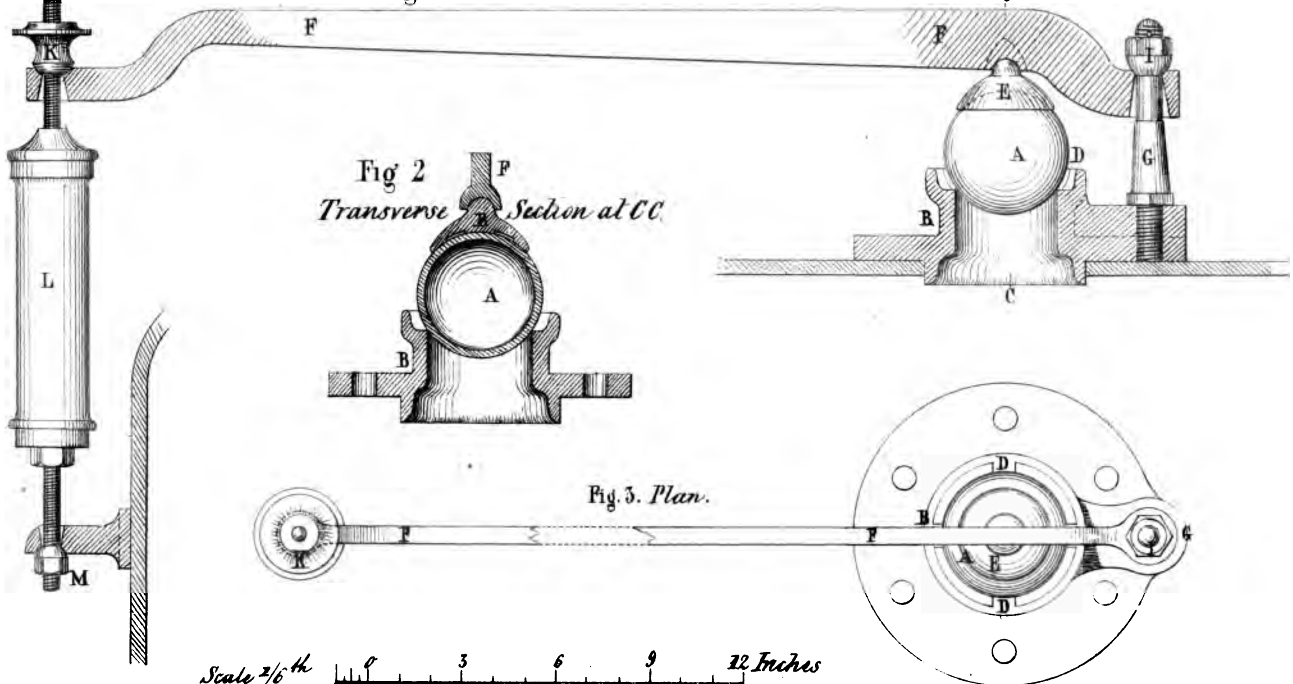

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Plate 6.

IMPROVED SAFETY VALVE

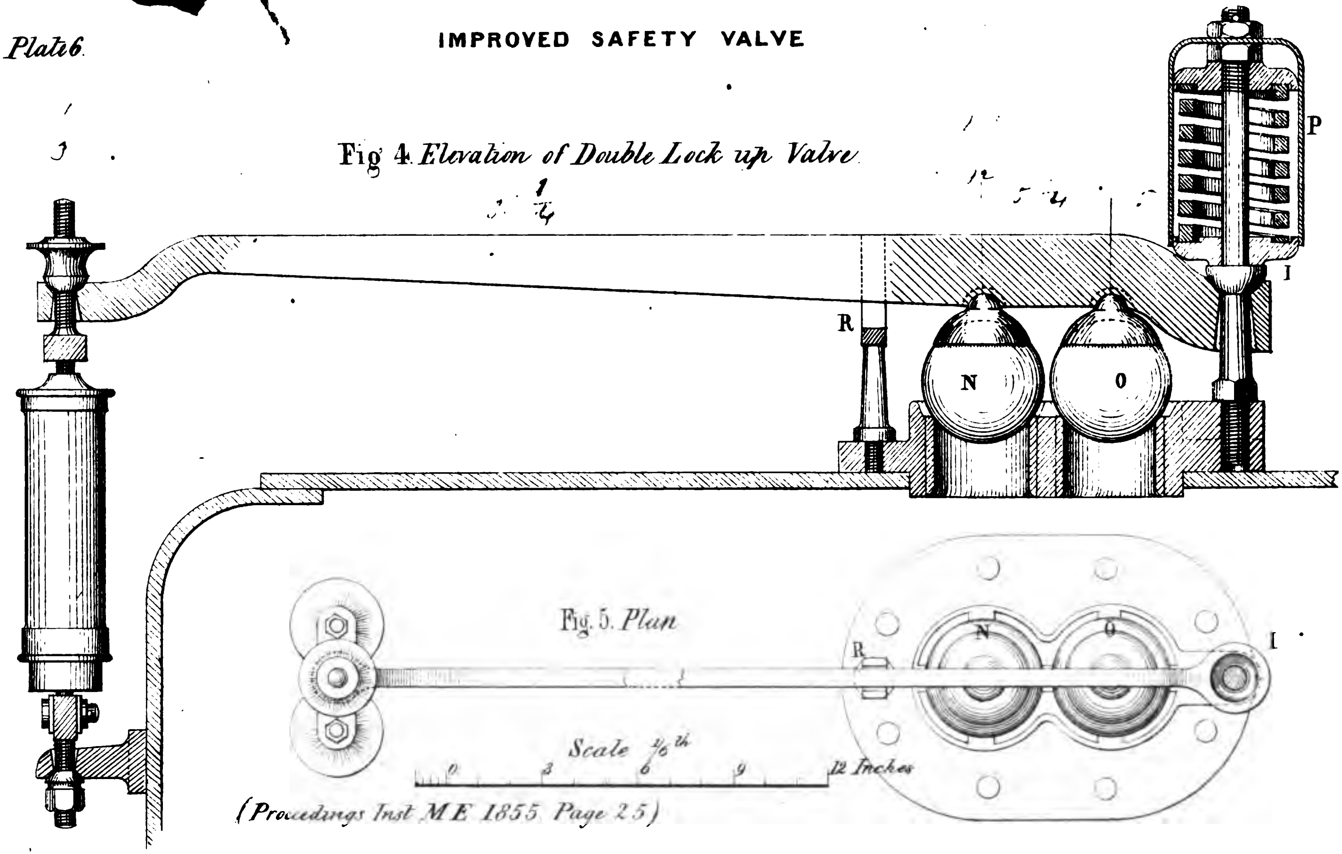

Fig. 4. *Elevation of Double Lock up Valve*

Fig. 5. *Plan*

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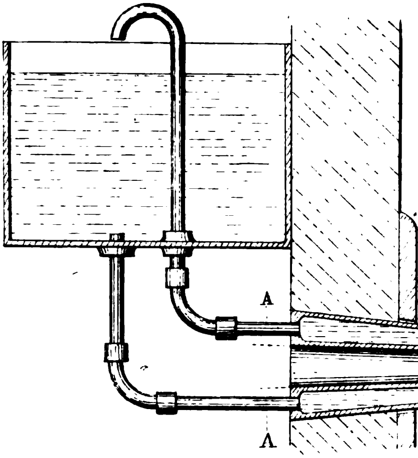


Fig 1.
Ordinary Water Tuyere

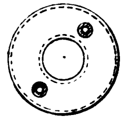


Fig. 2.
Section at AA

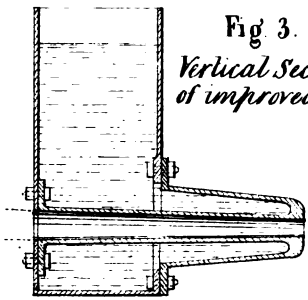


Fig 3.
Vertical Section of improved Tuyere

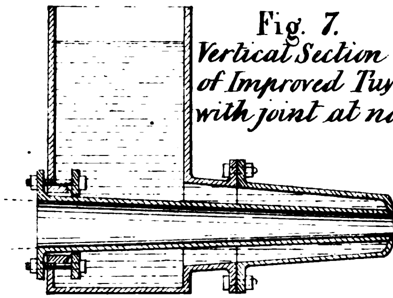


Fig. 7.
Vertical Section of Improved Tuyere with joint at nozzle

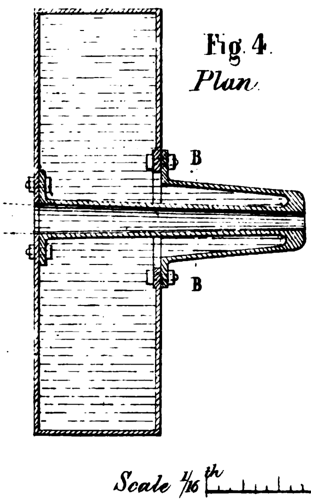


Fig 4.
Plan

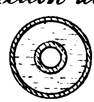


Fig. 5.
Section at BB

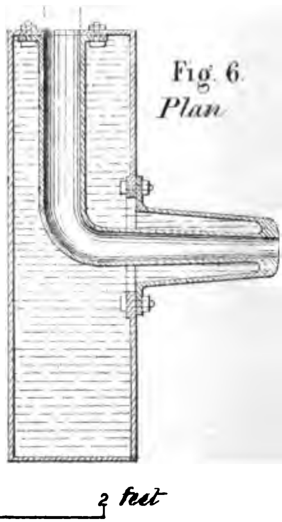


Fig 6.
Plan

Scale 1/16th


feet

Plate 8.

IMPROVD WATER TUYERE

Fig. 8. Vertical Section of Wrought Iron Tuyere.

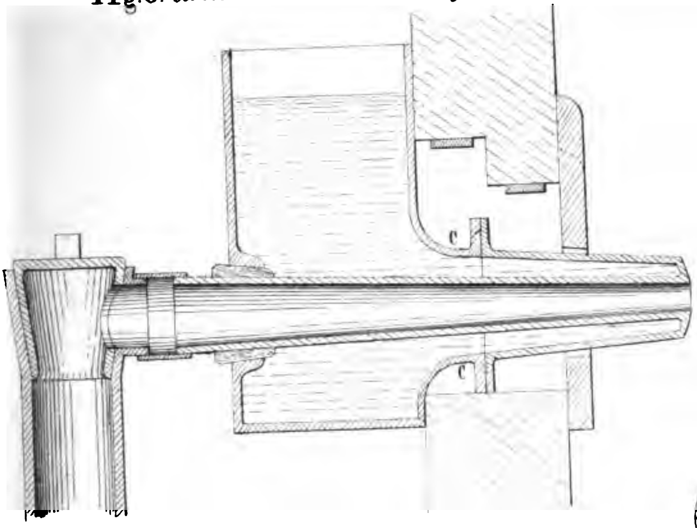
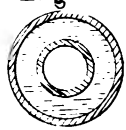
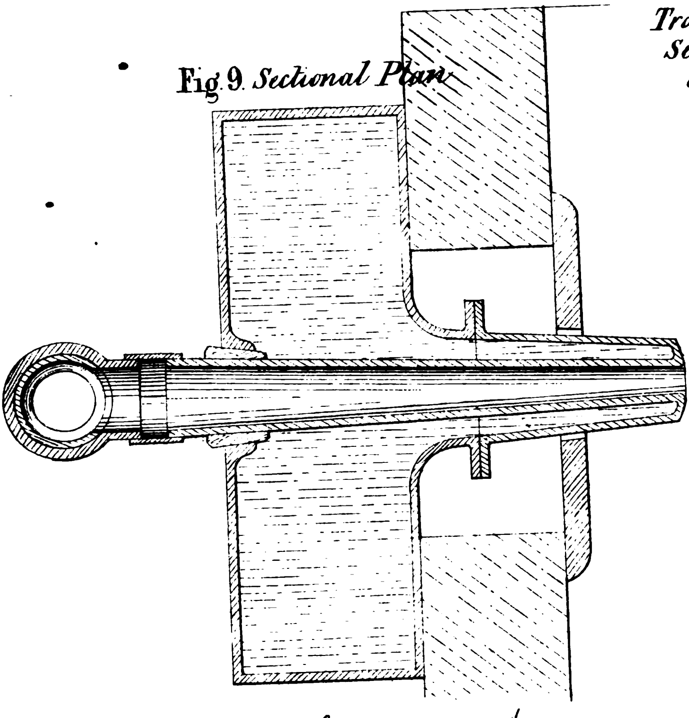


Fig 10



Transverse Section at C.C.

Fig. 9. Sectional Plan



Scale 1/12th 0 1 2 feet

Fig. 1.
Side Elevation

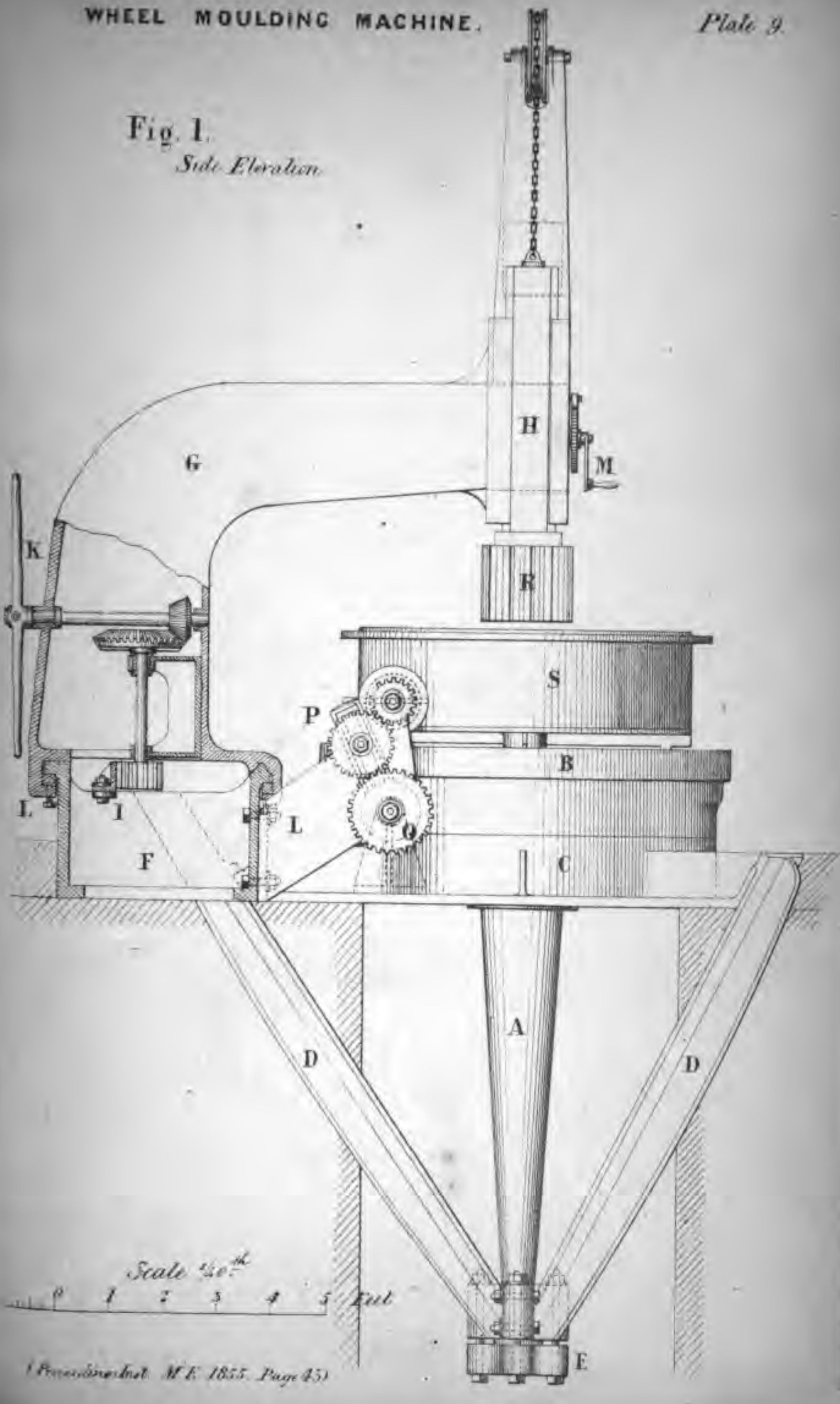
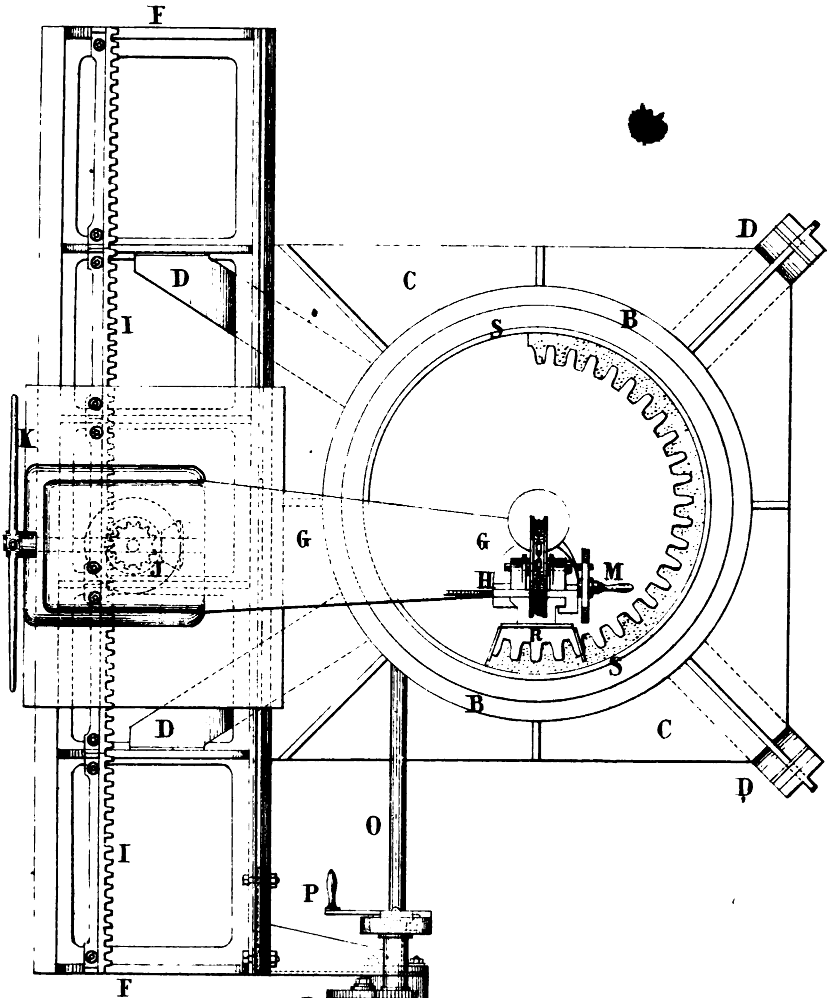


Fig. 2. *Plan.*



Scale 1/40th 0 1 2 3 4 5 6 7 8 9 *Feet*

WHEEL MOULDING MACHINE. *Plate 11.*

Fig. 3. *Vertical Section of Table and Moulding-Box.*

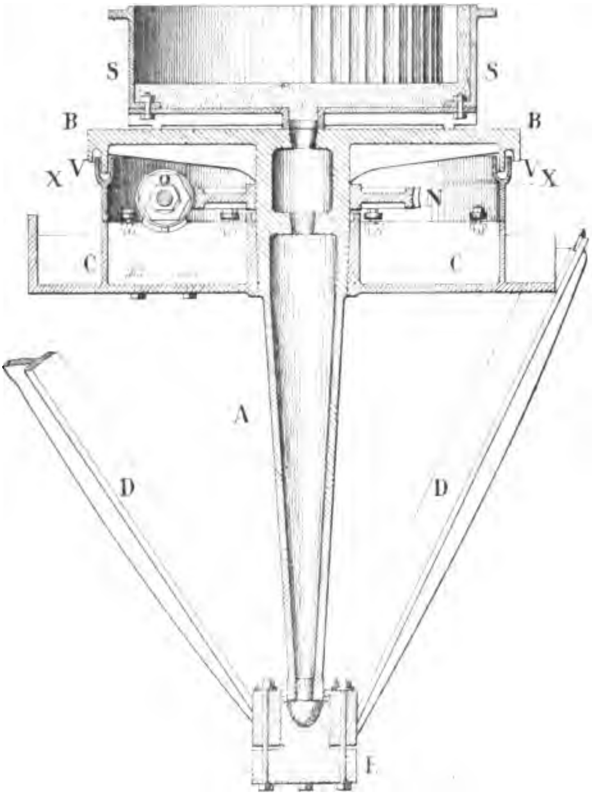
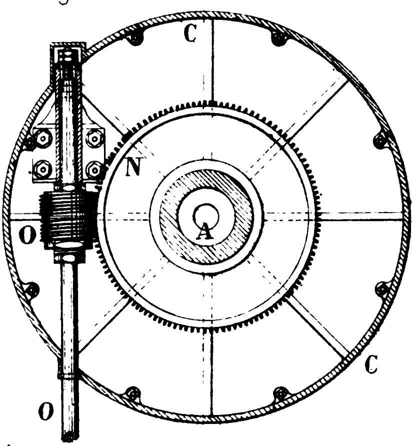


Fig. 4. *Sectional Plan at XX.*



Scale 1/40th 0 1 2 3 4 5 6 7 8 9 *Feet*

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WHEEL MOULDING MACHINE.

Fig. 4.
Plan of Vertical Slide.

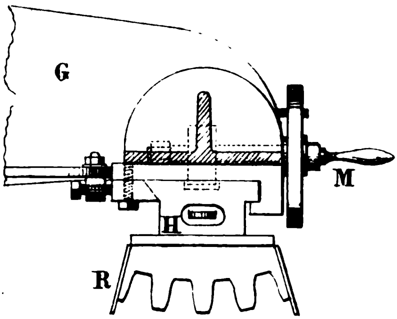


Fig. 5.
Elevation of Vertical Slide.

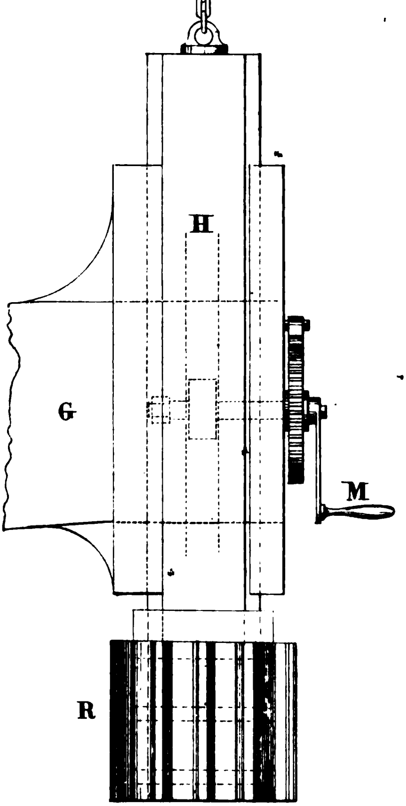
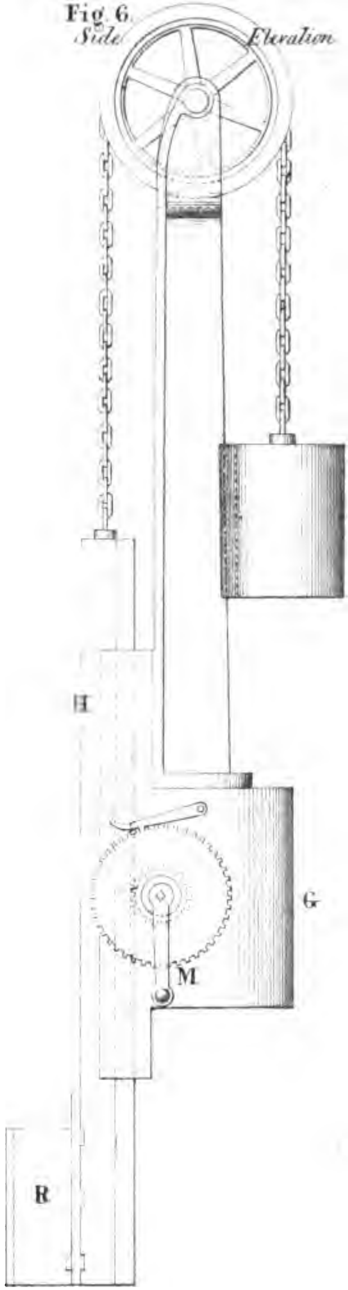


Fig. 6.
Side Elevation



Scale 1/20th 0 1 2 3 *Feet*

Fig. 1. *Cast Iron Tuyere.*

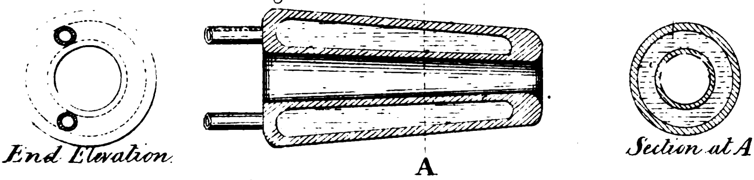


Fig. 2. *Tuyere with Cover-plate*

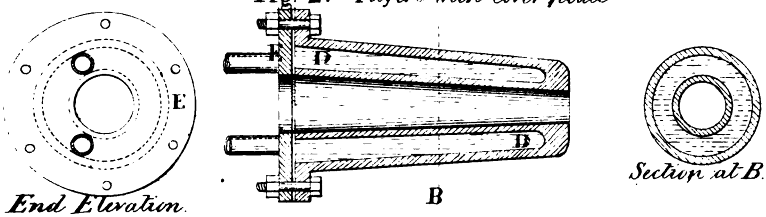


Fig. 3. *Improved Cast Iron Tuyere.*

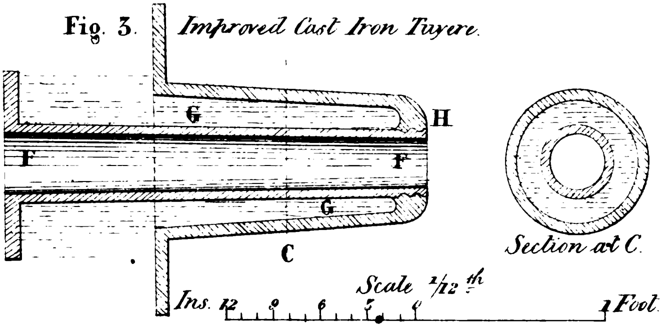
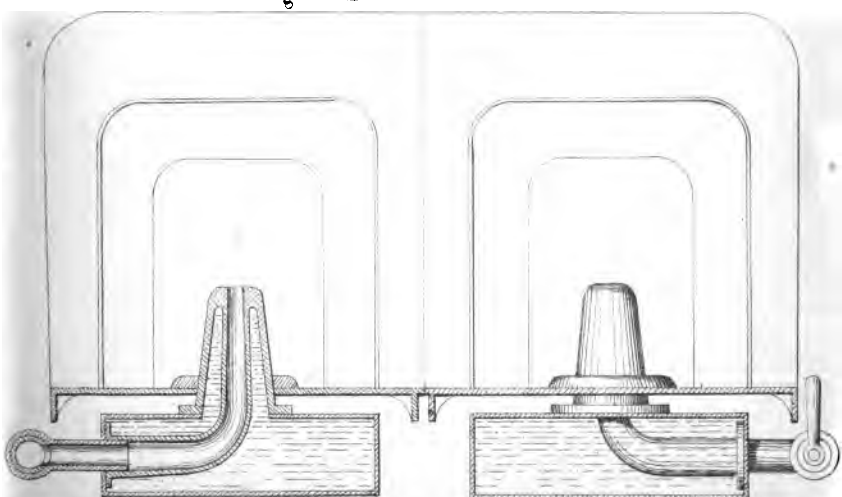


Fig. 4. *Plan of Double Hearth.*



(Proceedings Inst. M.E. 1855 Page 57.) *Scale 1/24th* 0 1 2 *3 Feet*

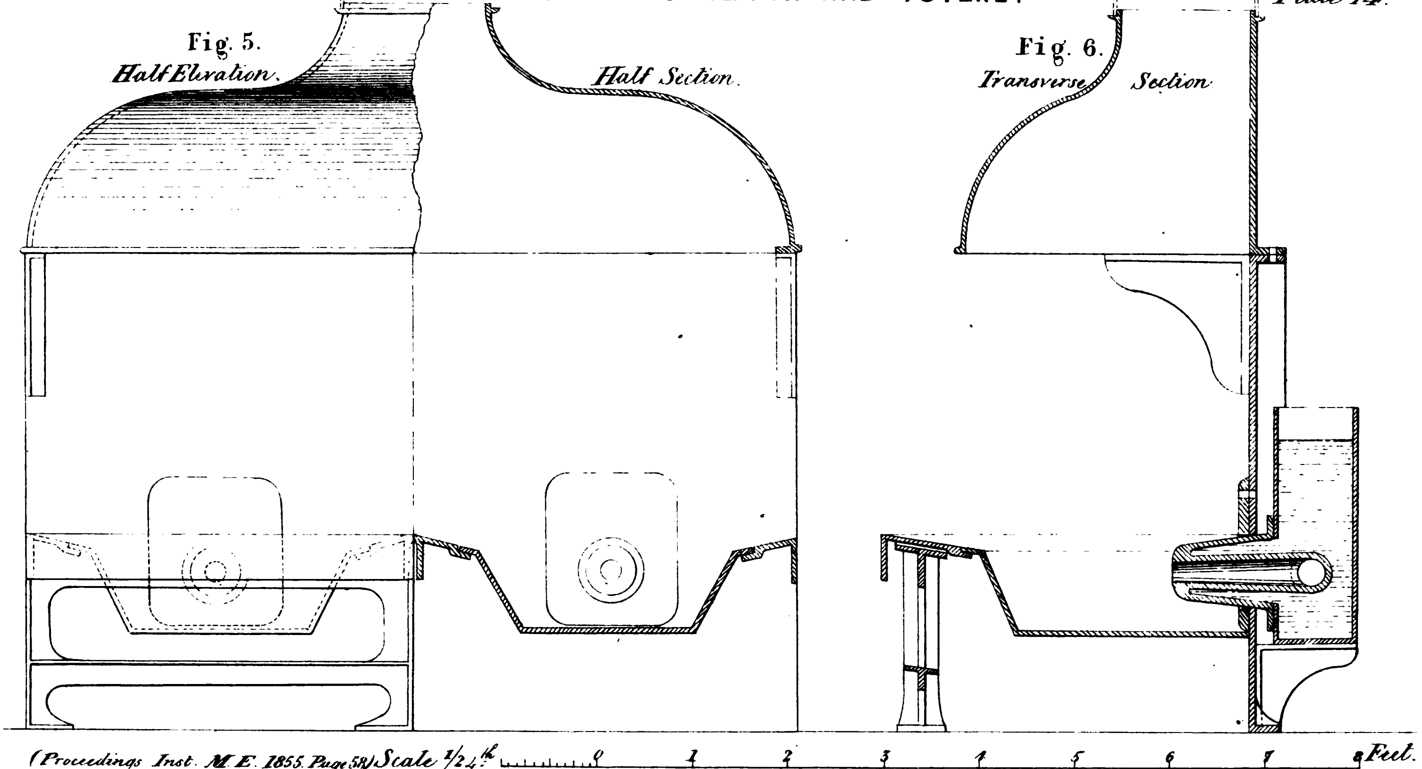
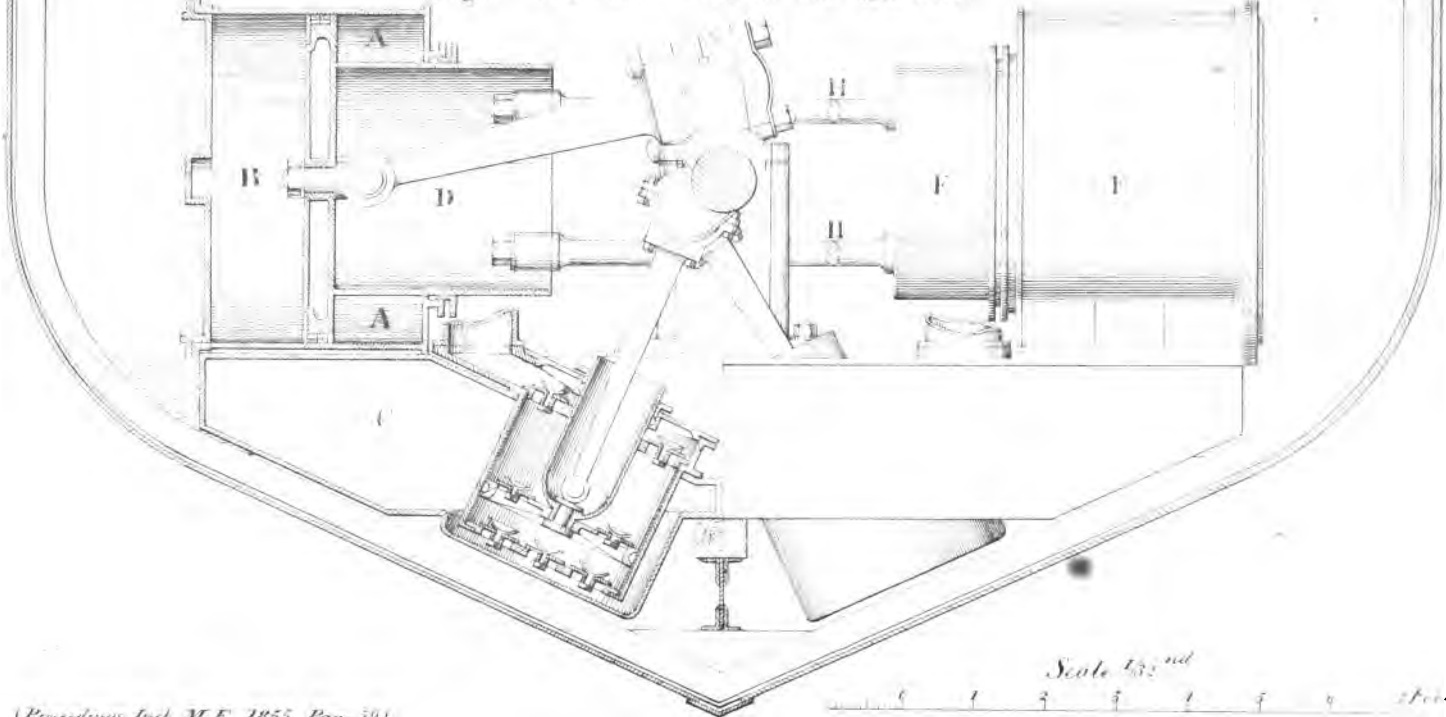


Fig. 5.
Half Elevation.
Half Section.
Fig. 6.
Transverse Section.
Scale 1/24th
0
1
2
3
4
5
6
7
8 Feet.

COMBINED-TRUNK DOUBLE EXPANSIVE MARINE ENGINE.

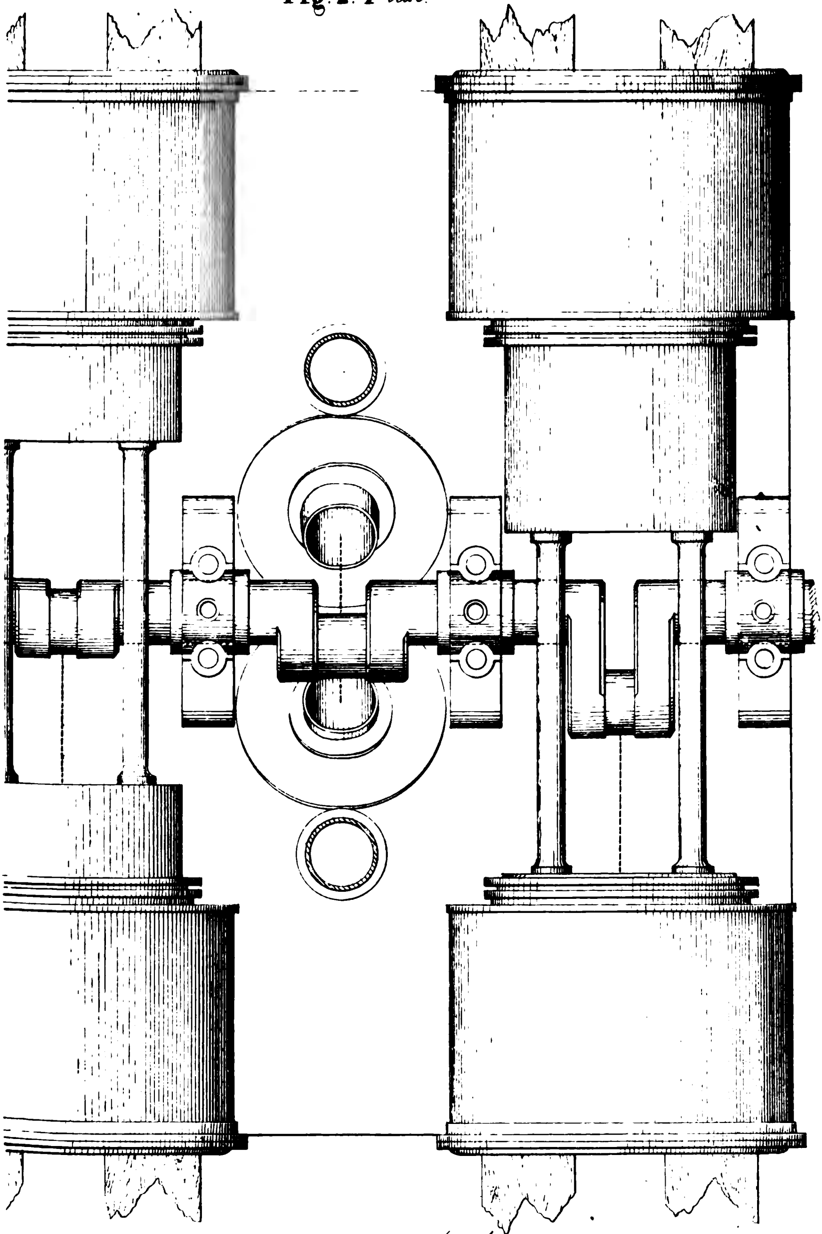
Fig 1. Longitudinal Section and Elevation



COMBINED - TRUNK
DOUBLE EXPANSIVE MARINE ENGINE.

Plate 16.

Fig. 2. *Plan.*



Scale 1/32nd.

(Proceedings Inst: M. E. 1855. Page 59)

Plate 17.

COMPOUND CYLINDER
COMBINED TRUNK ENGINE.
Fig. 3.

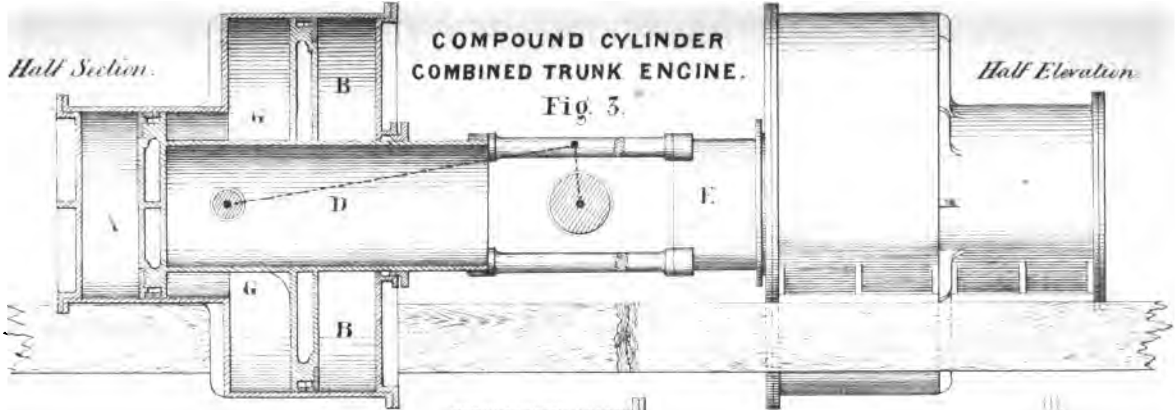
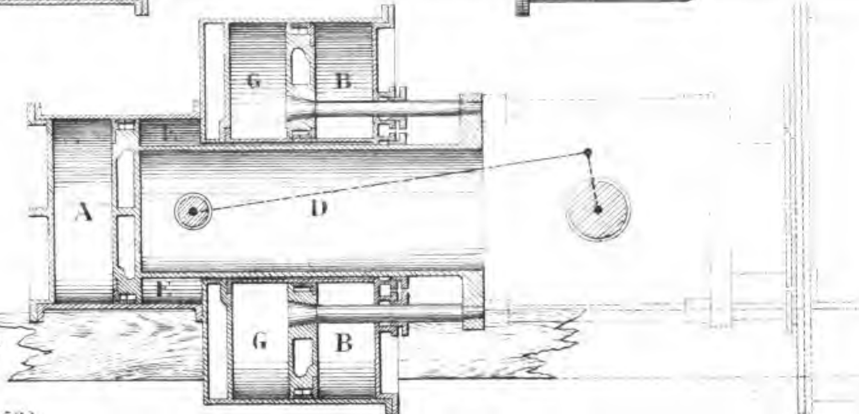


Fig. 4.

DOUBLE CYLINDER
TRUNK ENGINE.



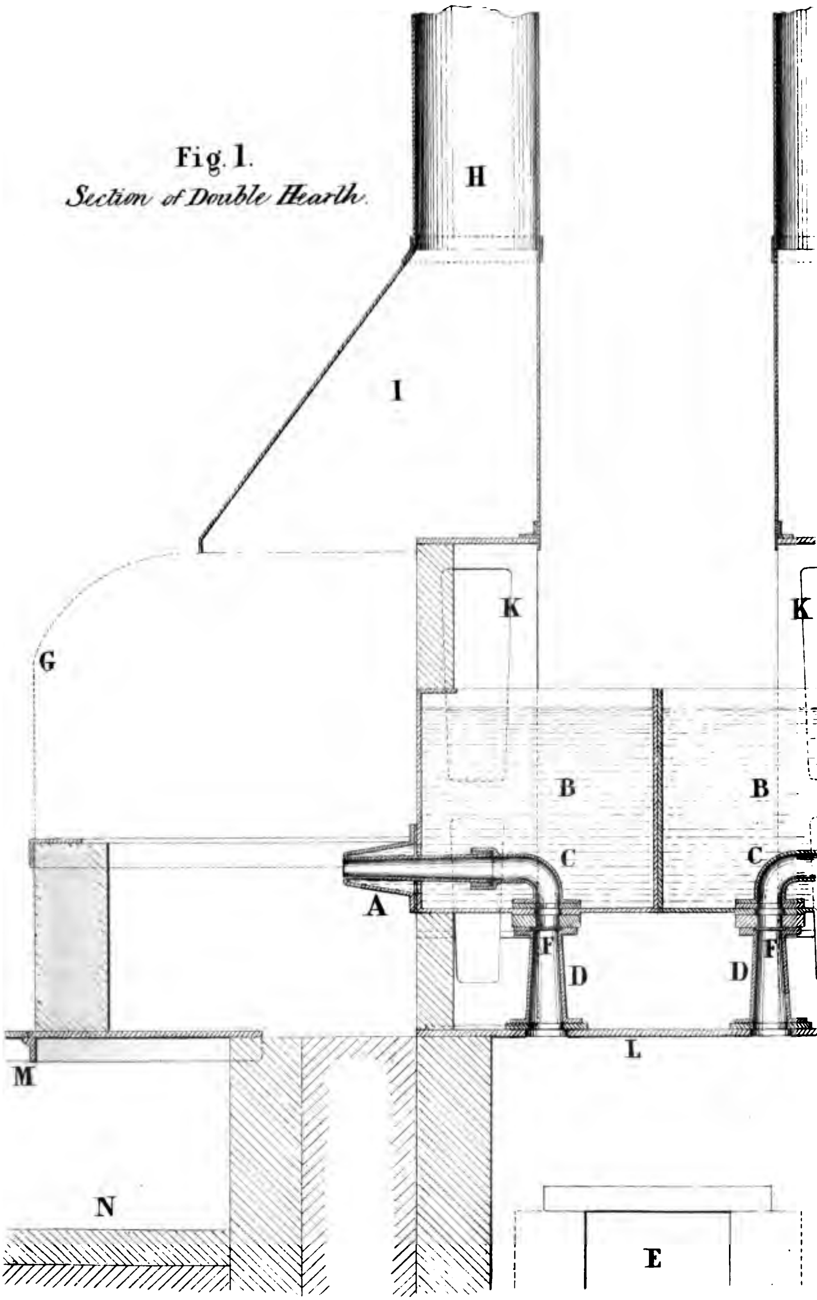
Scale 1/43rd

0 1 2 3 4 5 Feet

(Proceedings Inst. M. E. 1855. Page 59.)

Fig. 1.

Section of Double Hearth.



Scale 1/24th. Ins. 12 9 6 3 0 1 2 3 4 Feet

IMPROVED TUYERE AND HEARTH

Plate 19.

Fig. 2. *Transverse Section.*

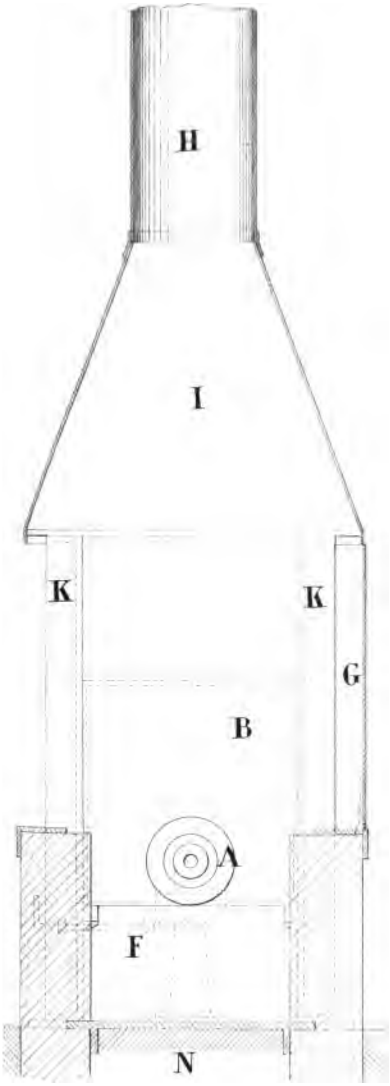


Fig. 3. *Plan of Double Hearth.*

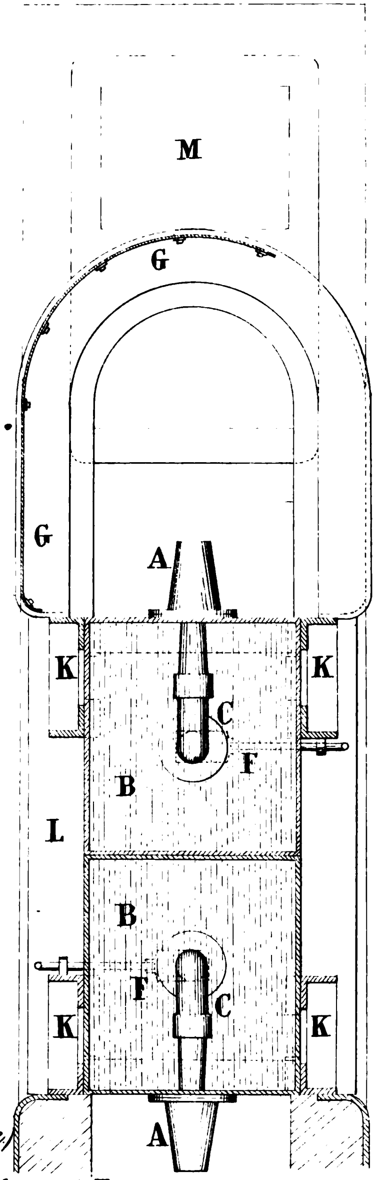
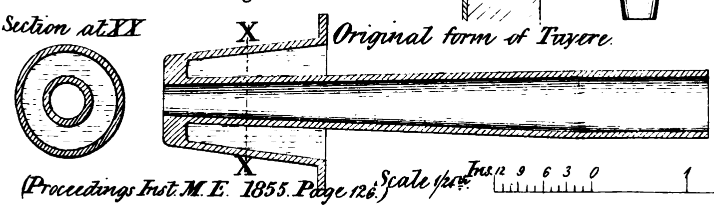


Fig. 4. *(Double Scale.)*



(Proceedings Inst. M. E. 1855. Page 126.) *Scale 1/24th* Ins. 12 9 6 3 0 1 2 Feet

Fig. 5.

Vertical Section of Circular Wheel Fire.

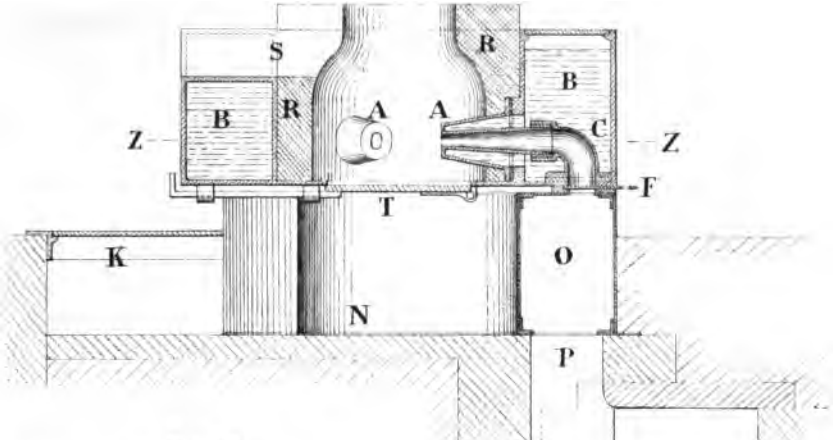


Fig. 7.

Enlarged Section of the Tuyere
(Double Scale)

Section at YY

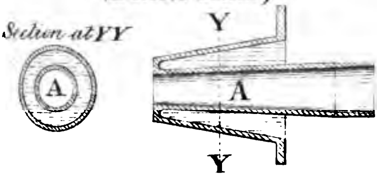
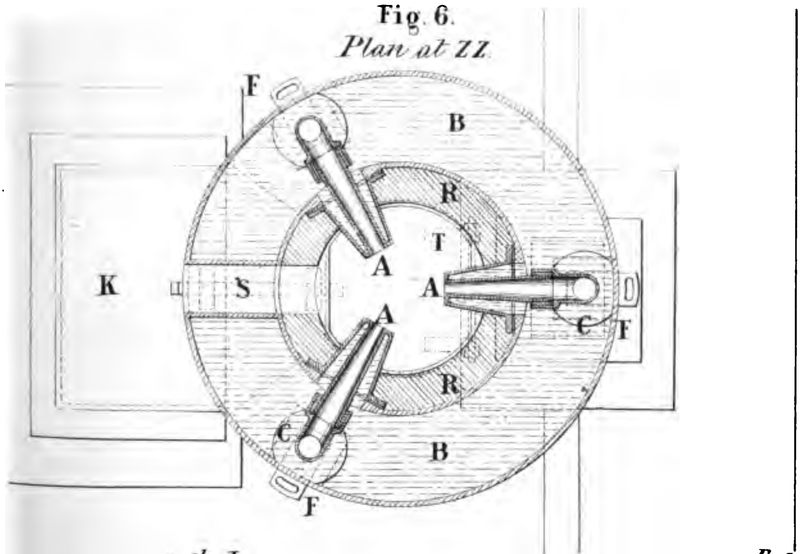


Fig. 6.

Plan at ZZ.



Scale 1/24th Ins. 12 9 6 3 0 1 2 3 4 Feet

(Proceedings Inst. M.E. 1855. Page 127.)

IMPROVED PRESSURE CAUGE.

Fig. 3. *Longitudinal Section.*

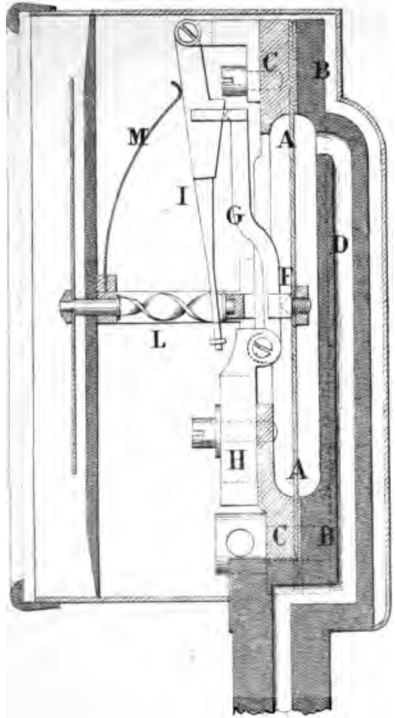


Fig. 4.

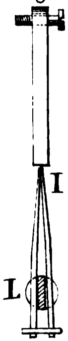
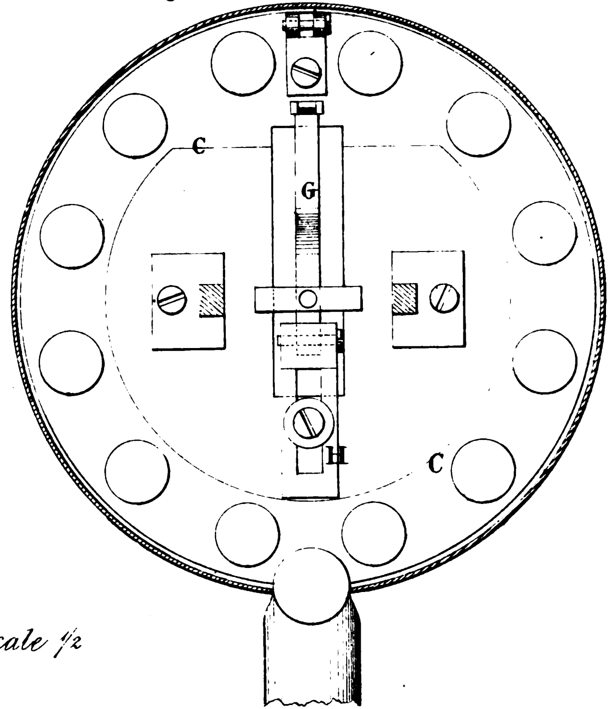
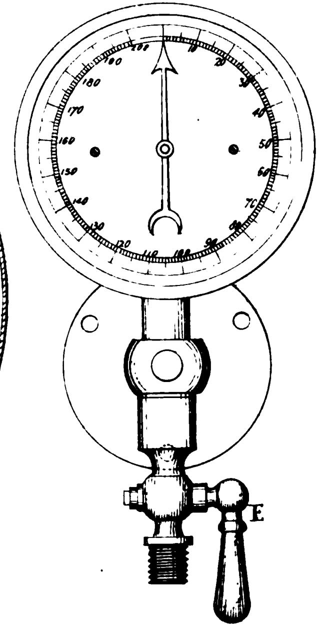


Fig. 2. *Sectional Elevation.*



Scale 1/2

Fig 1. *Front Elevation.*



Scale 1/4 th.

(Proceedings Inst. M.E. 1855. Page 130.)

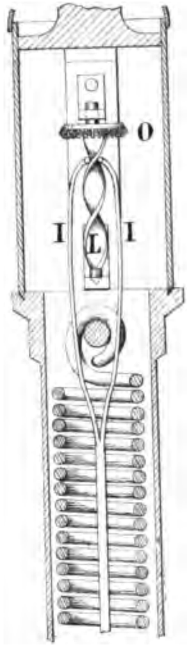
SPRING BALANCE.

Fig. 5.
Front Elevation.

Fig. 6.
Longitudinal Section.

Scale 1/6th

Fig. 7.
Transverse Section.



Scale 1/3rd

WATER GAUGE.

Fig. 8.
Elevation of Dial

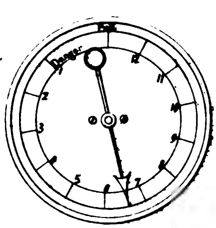


Fig. 9.
Longitudinal Section.

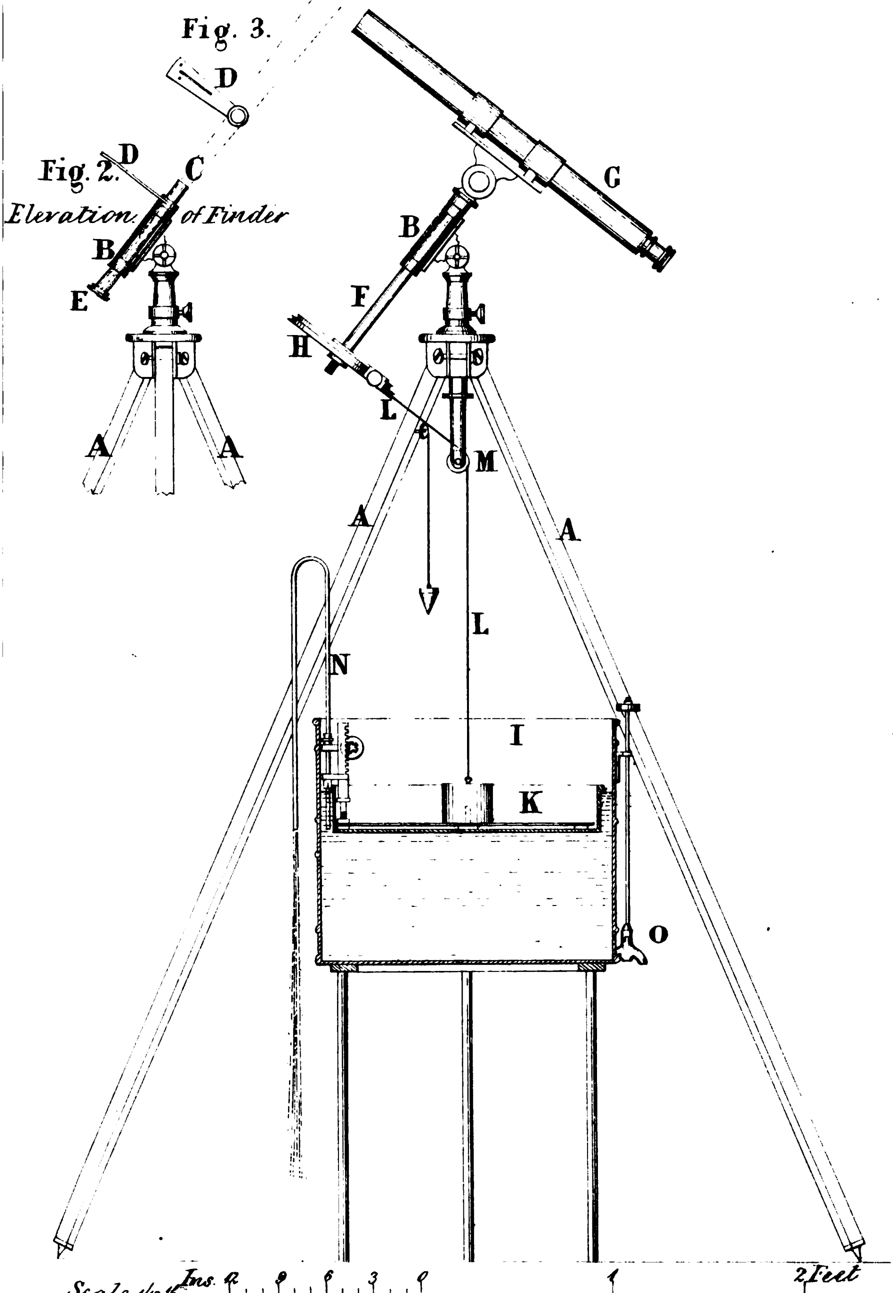
Scale 1/6th 0 1 2 3 4 5 6 7 8 9 10 11 12 Ins.

(Proceedings Inst. M. E. 1855. Page 134.)

EQUATORIAL TELESCOPE.

Plate 23.

Fig. 1. *Sectional Elevation.*



Scale 1/12th

(Proceedings Inst. M.E. 1855. Page 138.)

VALVE MOTION.

Plate 24.

Fig. 1. *Plan.*

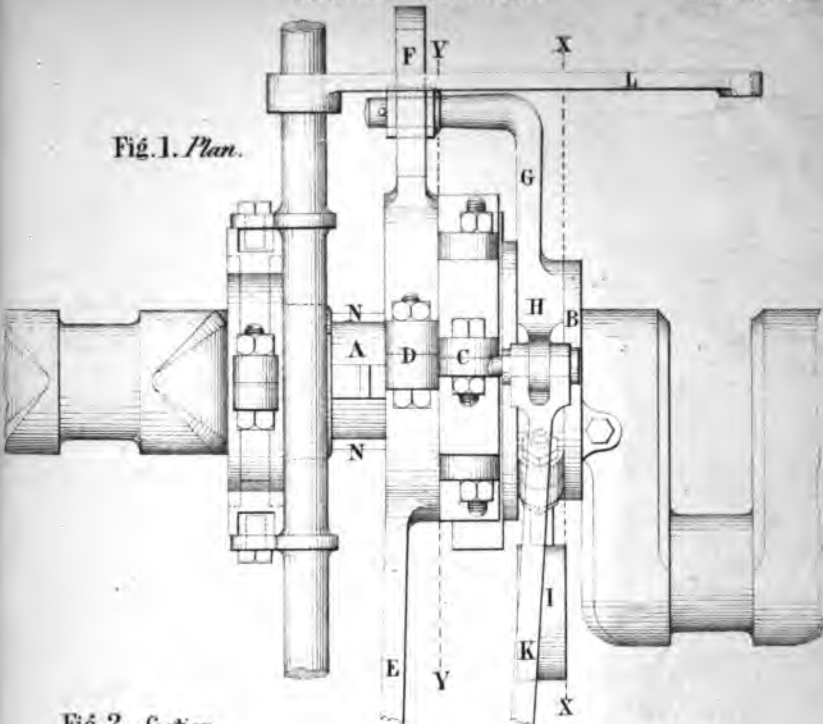
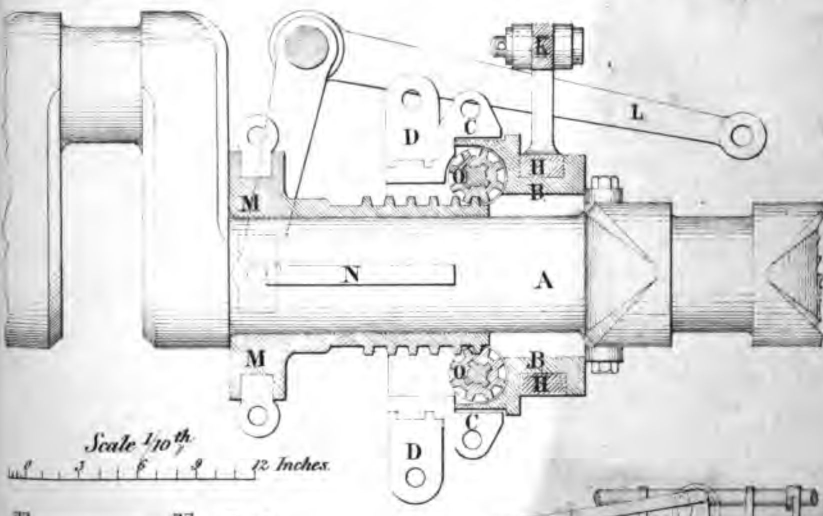


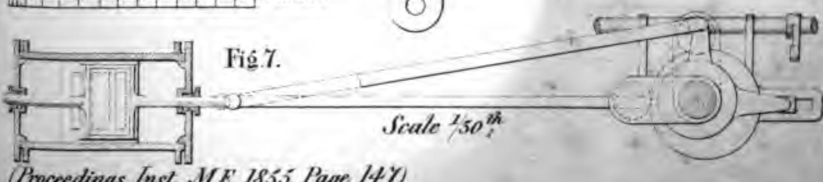
Fig. 2. *Section.*



Scale 1/10th.

0 3 6 9 12 *Inches.*

Fig. 7.



(Proceedings Inst. M.E. 1855. Page 147)

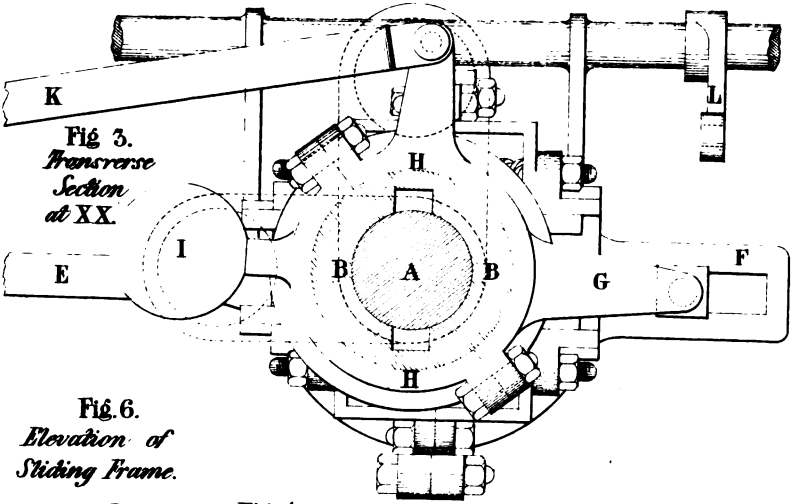


Fig 3.
Transverse Section at XX.

Fig. 6.
Elevation of Sliding Frame.

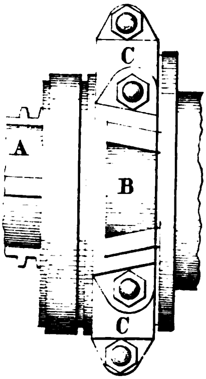
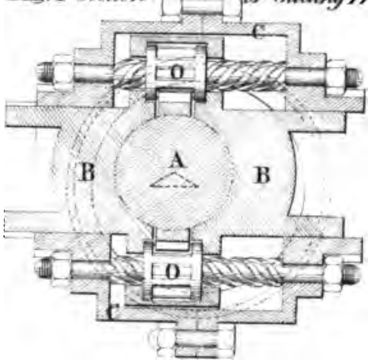


Fig. 4 *Section of Sliding Frame*



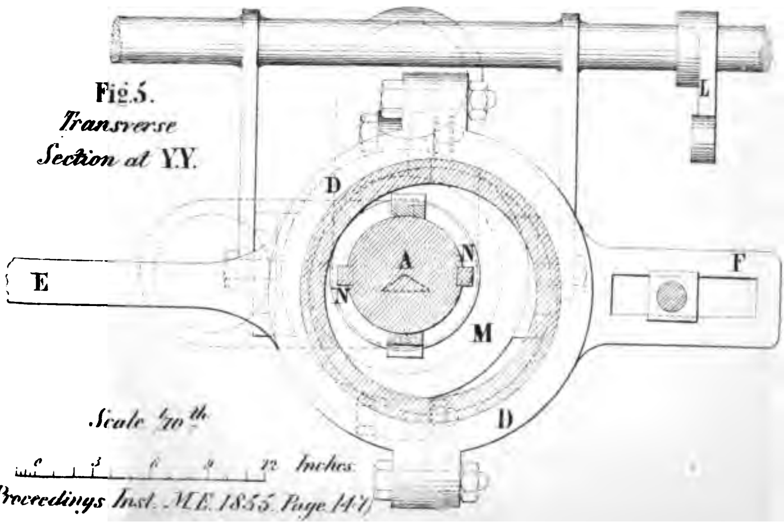


Fig. 5.
Transverse Section at Y.Y.

Scale 1/20th

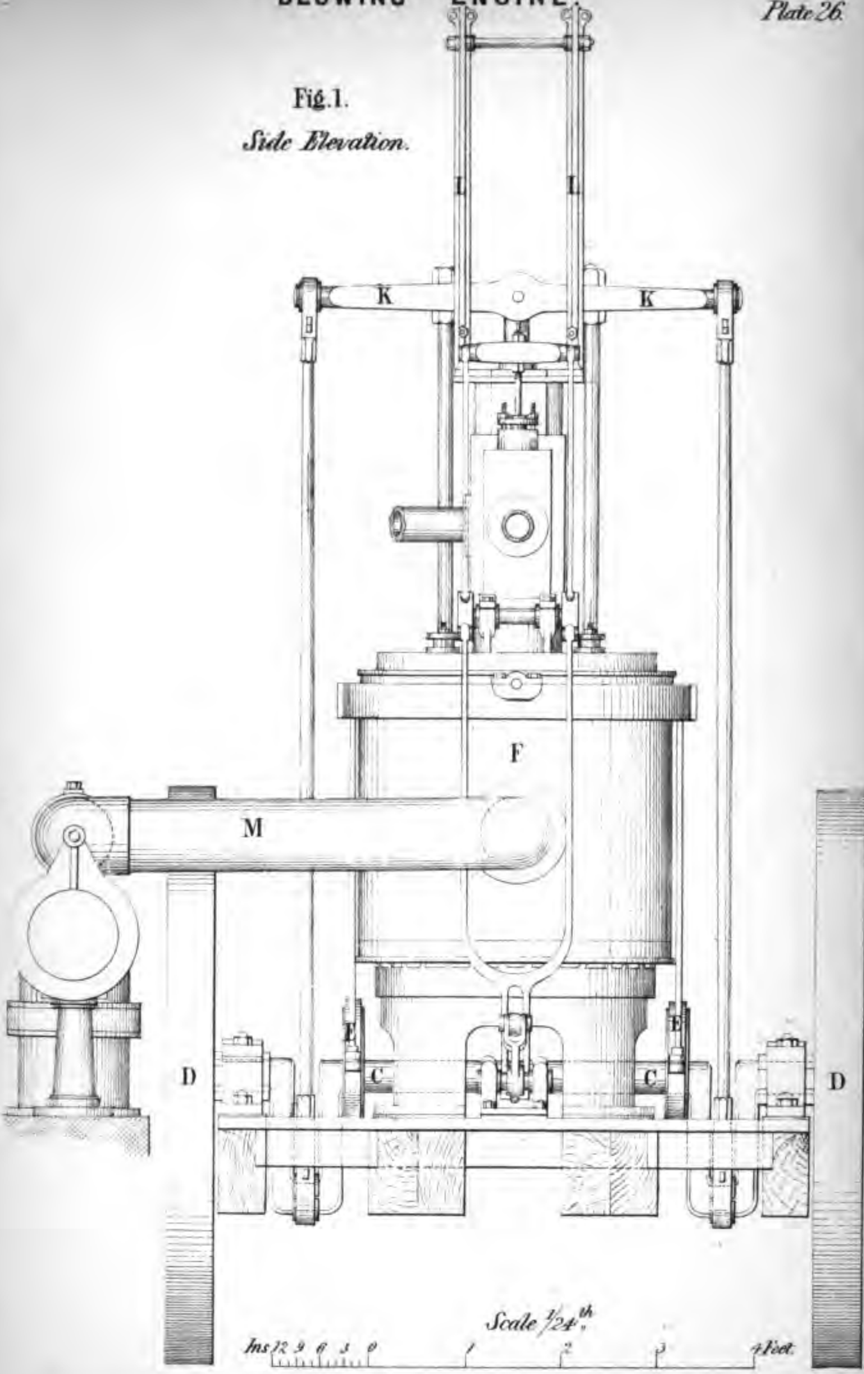
6 3 6 9 12 *Inches*

BLOWING ENGINE.

Plate 26.

Fig. 1.

Side Elevation.

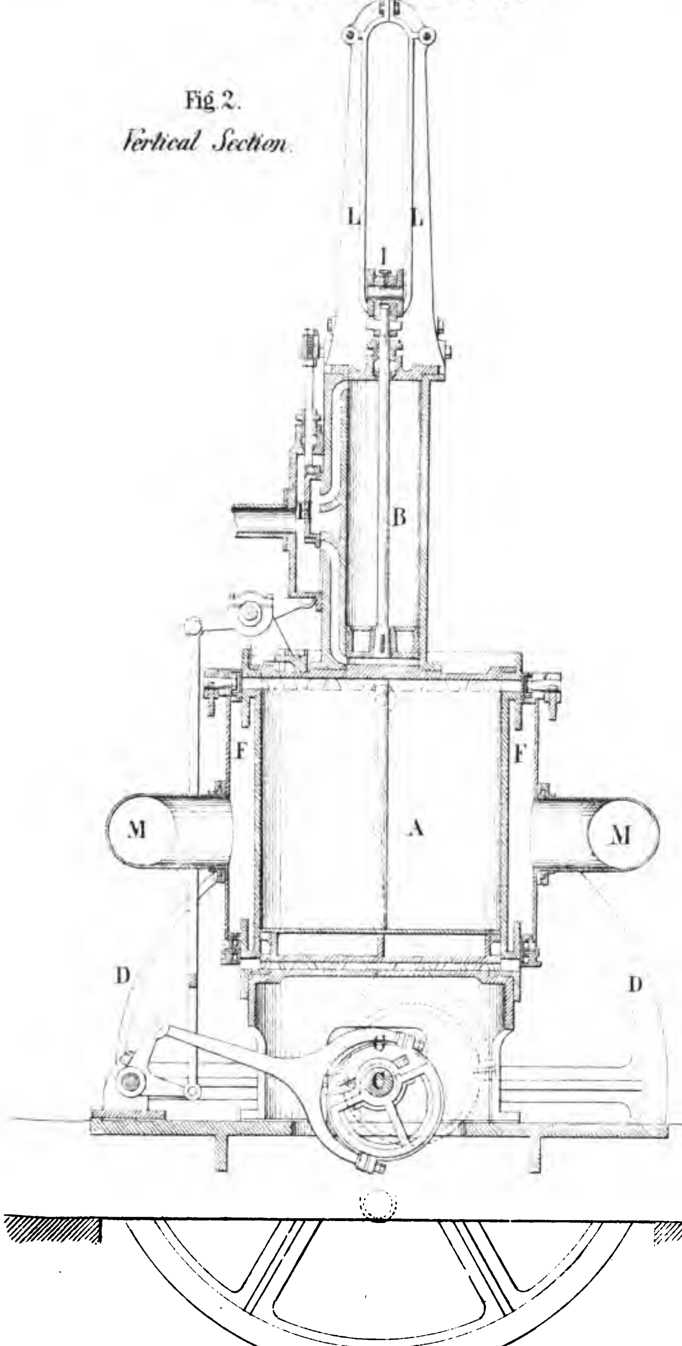


Scale 1/24th.

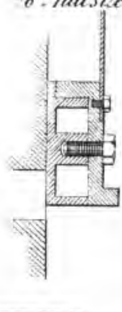
Ins 12 9 6 3 0 1 2 3 4 Feet

Fig. 2.

Vertical Section.



Section of Air Valve 1/6th full size.



Scale 1/24th Ins. 12 9 6 3 0 1 2 3 4 Feet.

(Proceedings Inst. M.E. 1855. Page 155.)

BLOWING ENGINE.

Fig. 3. *Plan.*

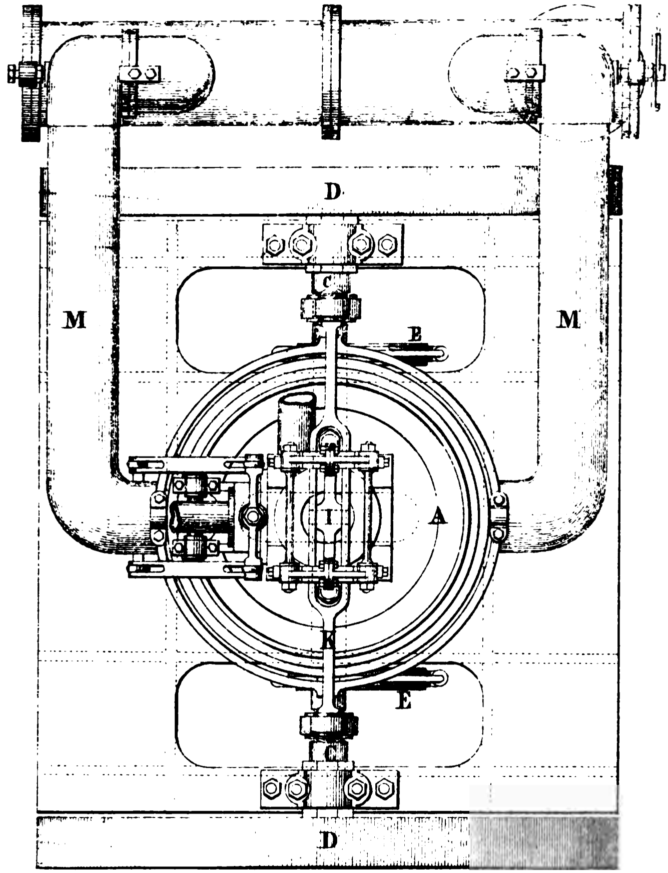
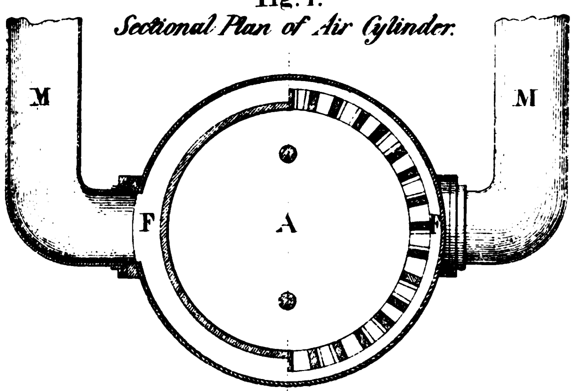


Fig. 4.

Sectional Plan of Air Cylinder.



Scale 1/24th Ins 12 9 6 3 0 1 2 3 4 *Feet.*

Fig. 5.
Ordinary Blowing Engine.

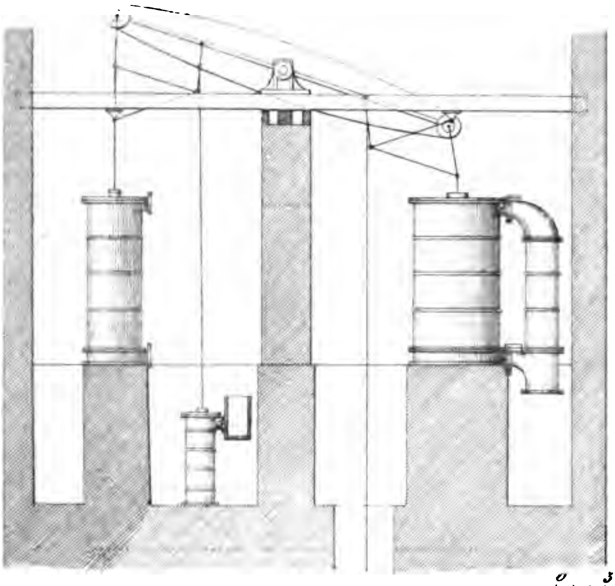


Fig. 6.
New Blowing Engine.

Scale 1/144th.
0 3 6 9 12 Feet.

Fig. 7. *Diagram from Air Cylinder of Ordinary Engine.*

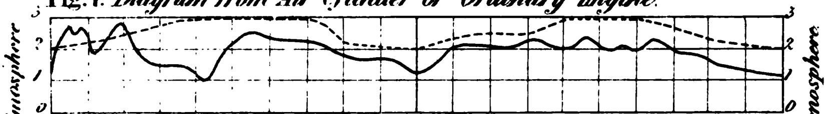


Fig. 8. *Diagram from Air Cylinder of New Engine.*

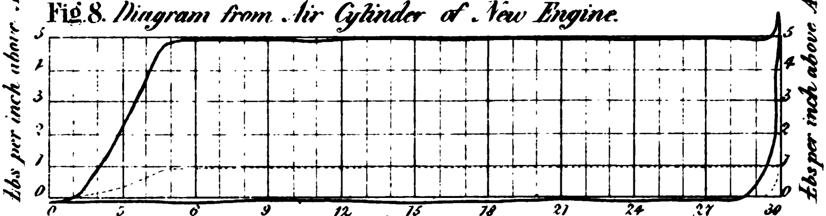
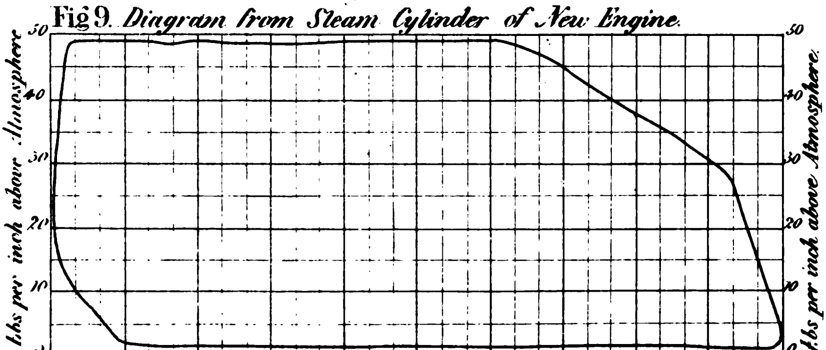


Fig. 9. *Diagram from Steam Cylinder of New Engine.*



RAILWAY SPRING. *Plate 30.*

Fig. 1. *Ordinary Bearing Spring.*

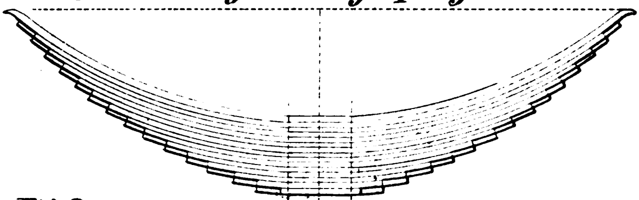
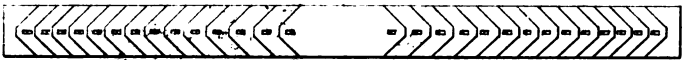
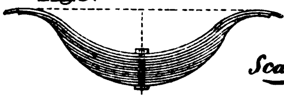


Fig. 2. *Plan.*



Old Bearing Spring.

Fig. 3.



Scale 1/24th.

Fig. 4.

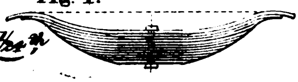


Fig. 5. *Improved Bearing Spring.*

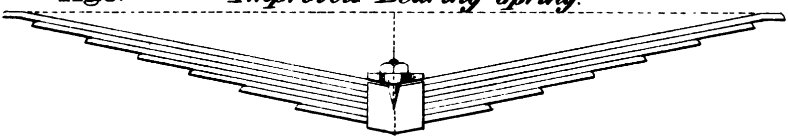


Fig. 6.

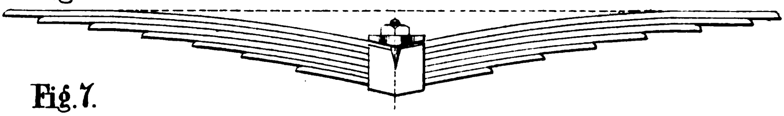


Fig. 7.

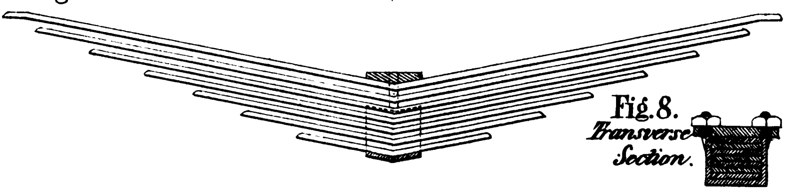


Fig. 8. *Transverse Section.*

Fig. 9. *Plan.*

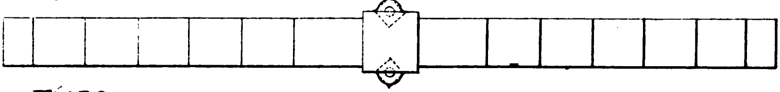


Fig. 10.

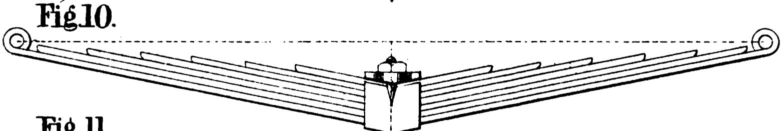
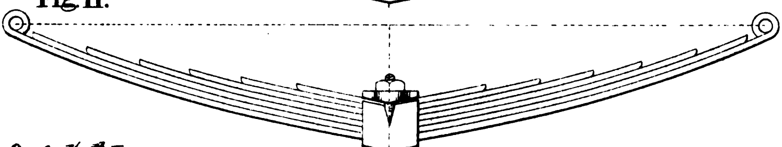


Fig. 11.



Scale 1/12th Ins. 12 9 6 3 0 1 2 *Feet*

(Proceedings Inst. M.E. 1855. Page 164.)

RAILWAY AXLEBOX.

Fig. 12.

Transverse Section of Axlebox.

Fig 13.
Longitudinal Section

Fig. 14.
Sectional Plan.

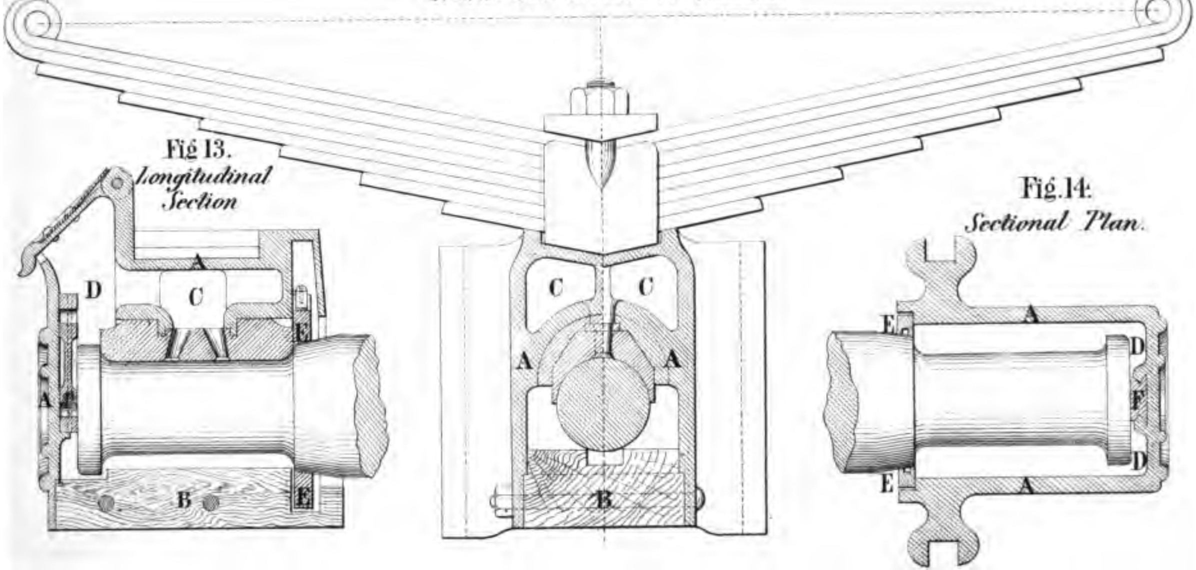
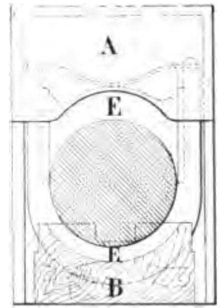


Fig. 15.
Elevation at Back.



Scale 1/6th 0 3 6 9 12 Inches.

IMPROVED PISTON.

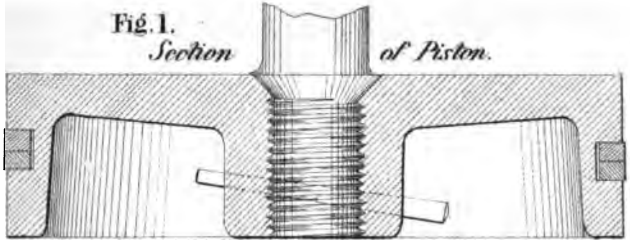


Fig. 1. Section of Piston.

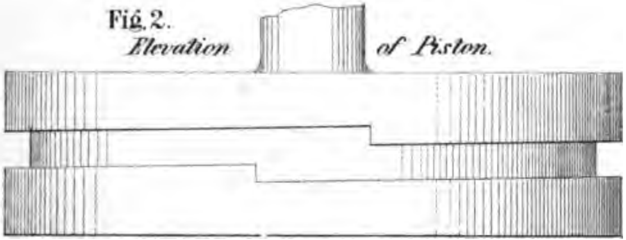


Fig. 2. Elevation of Piston.

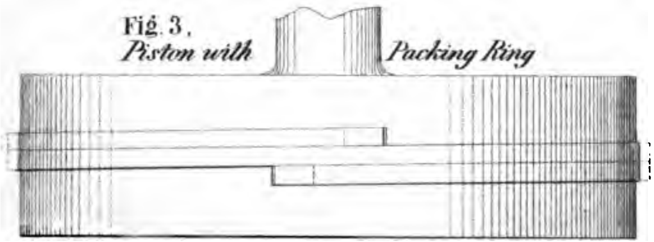


Fig. 3. Piston with Packing Ring

Fig. 4.

Fig. 5. Elevation of Packing Ring.

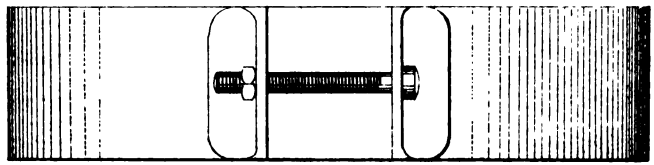


Fig. 6. Elevation of Cramp.

Fig. 7. Plan of Cramp.

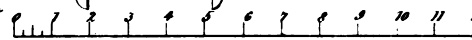
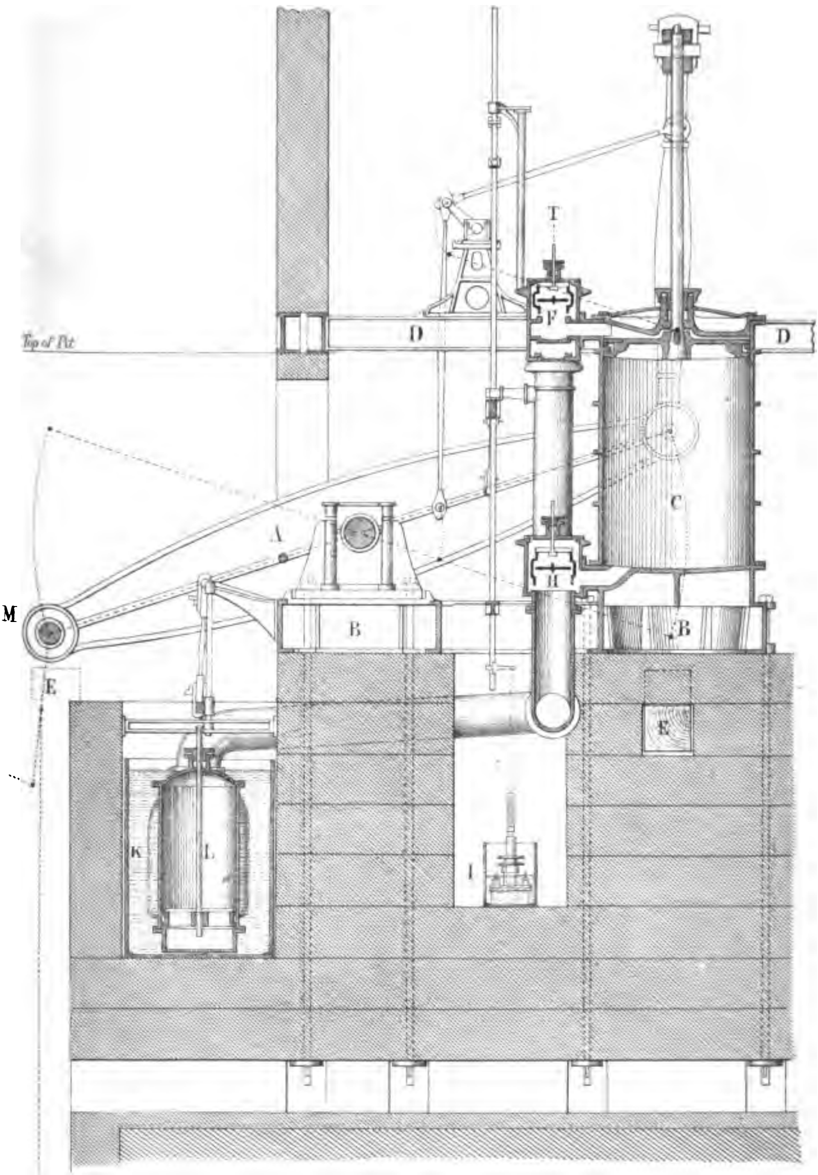


Fig. 1. *Longitudinal Section of Engine.*



Scale 1/90th 0 5 10 15 20 Feet

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Fig. 2. *Transverse Section of Engine.*

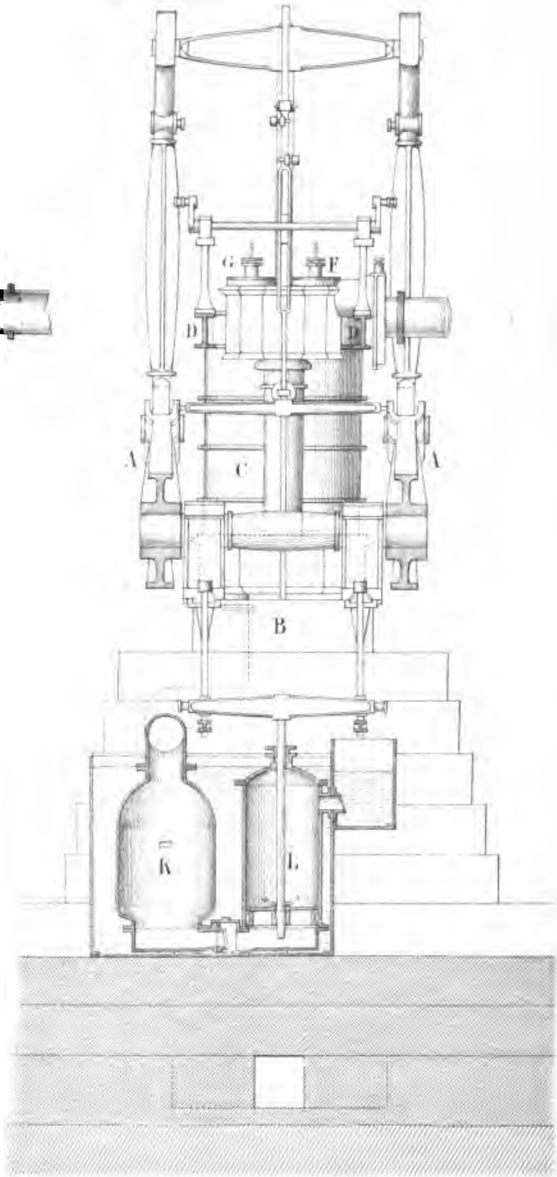
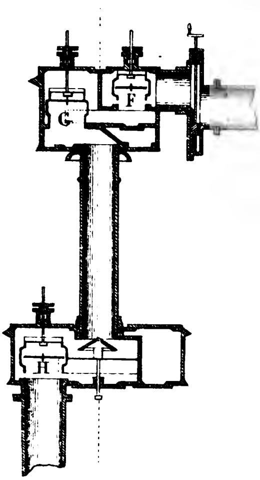


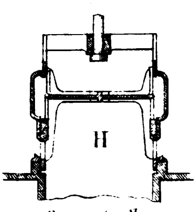
Fig. 3.

Section of Valves.

***at* T *in* Fig. 1.**



Detail of Valve.



Scale $^{1}/_{30}$th

Scale $^{1}/_{90}$th 0 5 10 15 20 Feet

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PUMPING ENGINE.

Fig. 4. General Elevation.

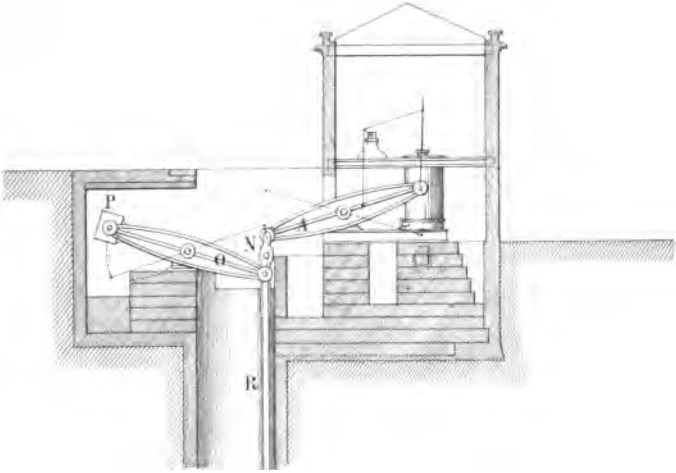
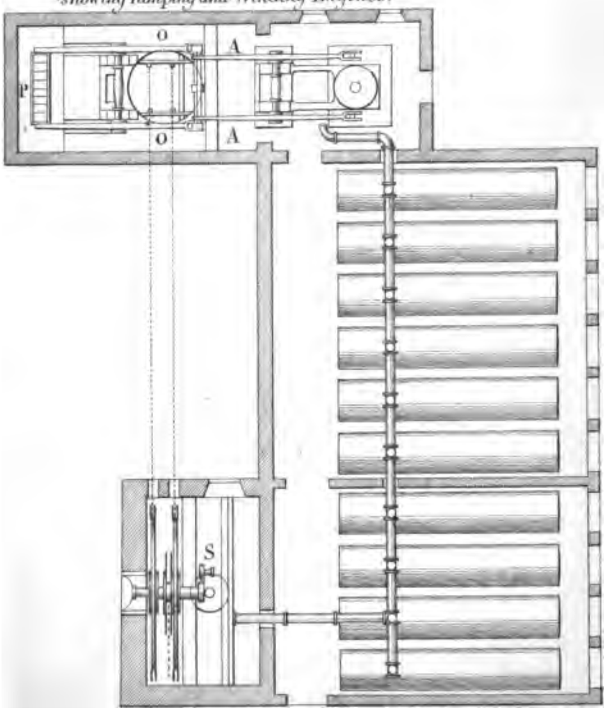


Fig 5. General Plan
showing Pumping and Winding Engines.



Scale 1/360th 0 5 10 20 30 40 50 60 70 80 90 100 Feet

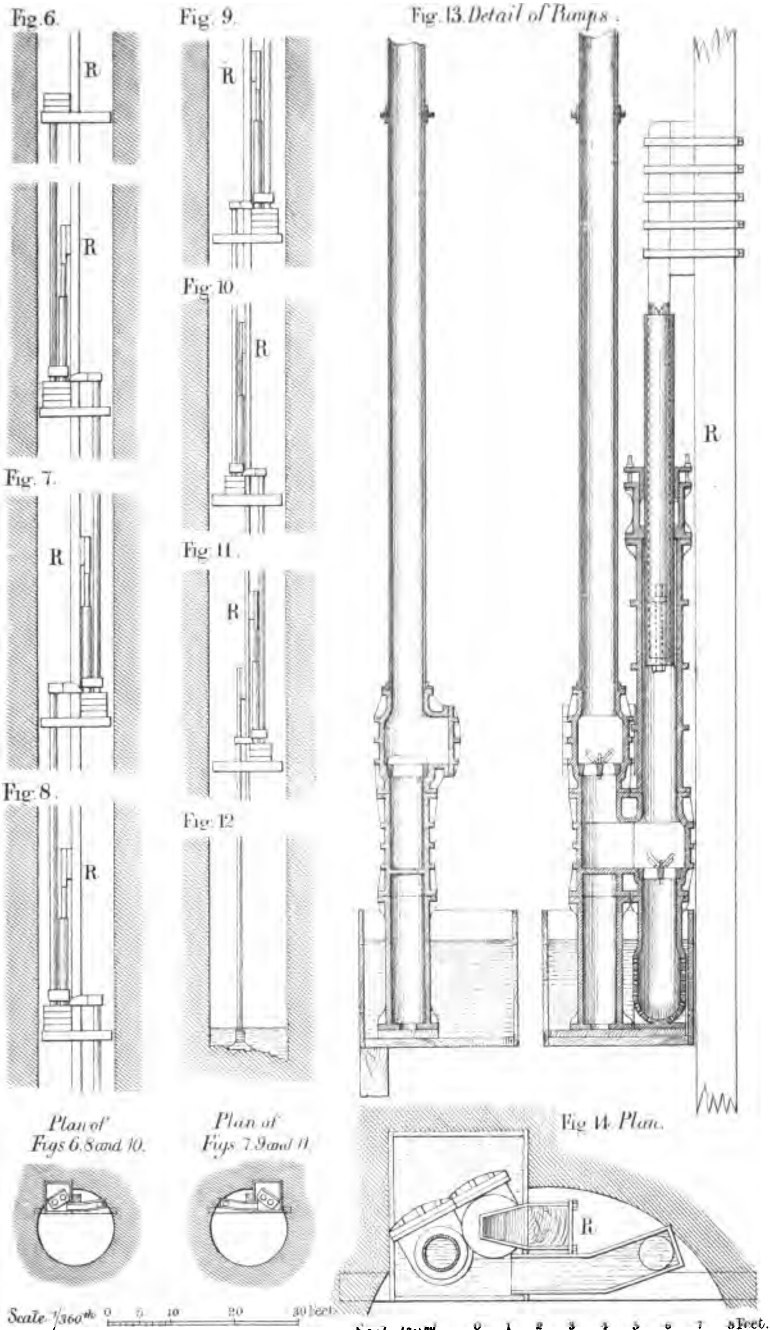


Fig. 6.
R
R
Fig. 7.
R
Fig. 8.
R
Fig. 9.
R
Fig. 10.
R
Fig. 11.
R
Fig. 12.
Fig. 13. Detail of Pumps.
R
Plan of Figs 6.8 and 10.
Plan of Figs 7.9 and 11.
Fig. 14. Plan.
R
Scale 1/360th 0 5 10 20 30 Feet.
Scale 1/72nd 0 1 2 3 4 5 6 7 8 Feet.

Fig. 1. *Ordinary Axlebox and Spring Fittings.*

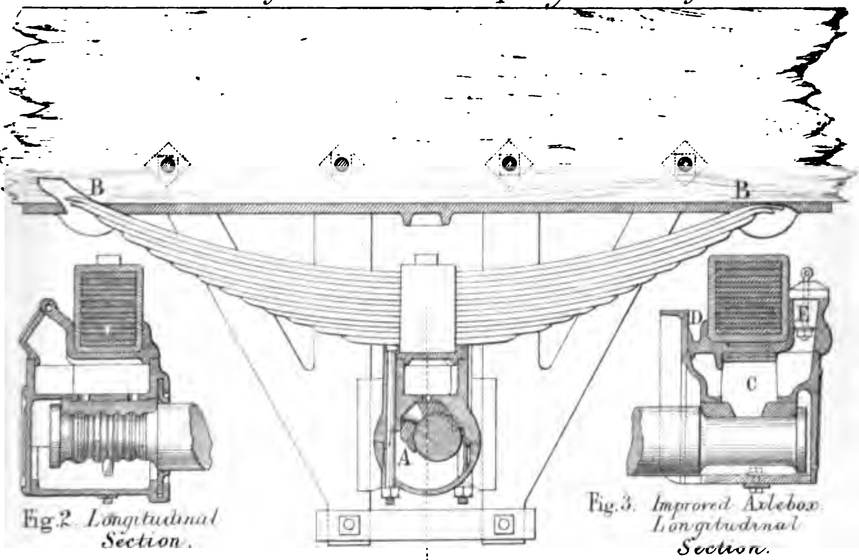


Fig. 2. *Longitudinal Section.*

Fig. 3. *Improved Axlebox Longitudinal Section.*

Fig. 6. *Improved Axlebox and Spring Fittings.*

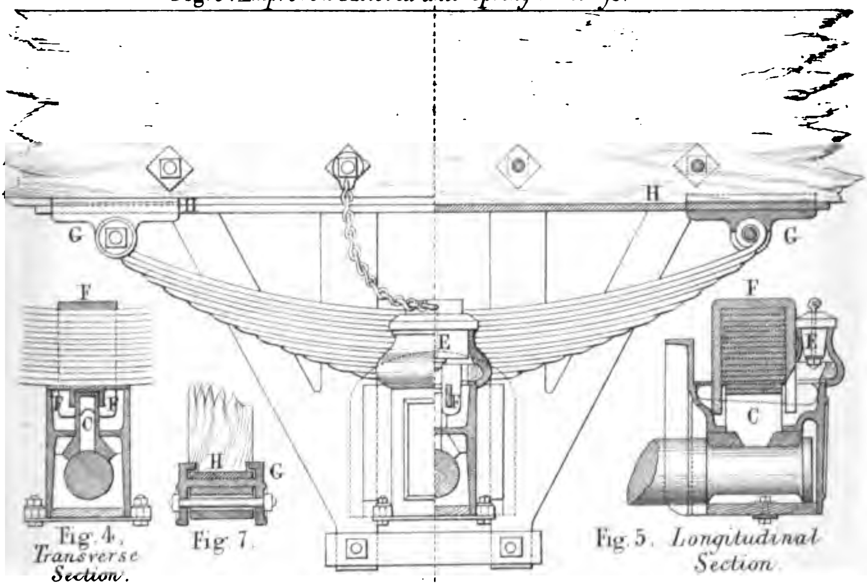


Fig. 4. *Transverse Section.*

Fig. 7.

Fig. 5. *Longitudinal Section.*

Scale 1/12th. Ins 12 9 6 3 0 1 2 Feet

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Fig. 1. *Plan.*

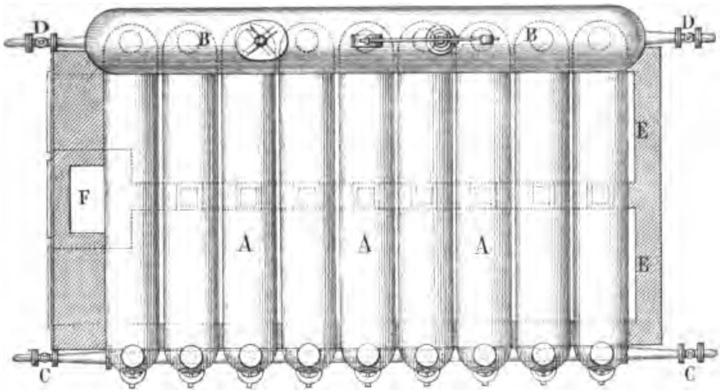


Fig. 2. *Longitudinal Section.*

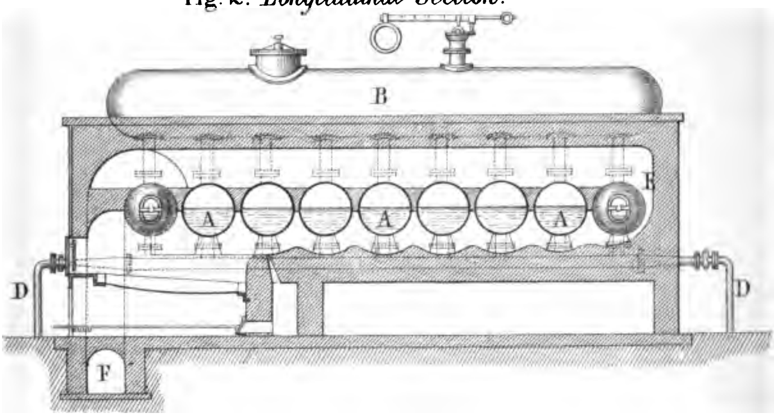


Fig. 3. *Transverse Section through Fire.*

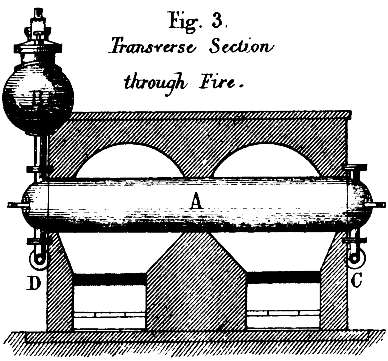
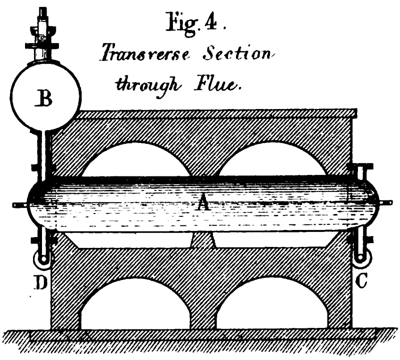


Fig. 4. *Transverse Section through Flue.*



Scale 1/60th Ins. 12 6 0 1 2 3 4 5 6 7 8 9 10 11 12 Feet.

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HORIZONTAL CONDENSING ENGINE.

Plate 39.

Fig. 1. *Longitudinal Section.*

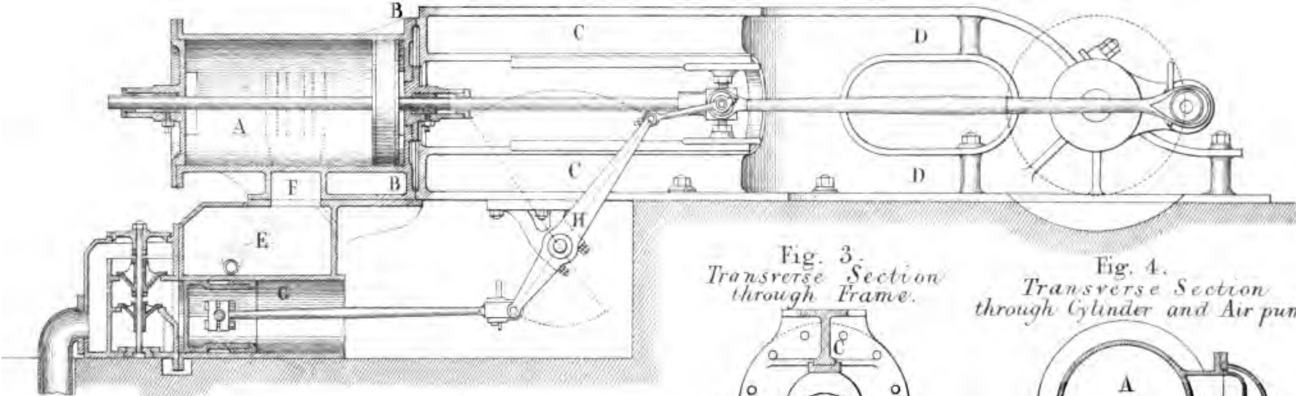
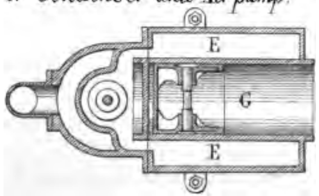


Fig: 2. *Sectional Plan of Condenser and Air pump.*



Scale 1/32nd.

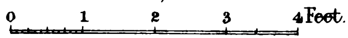


Fig. 3. *Transverse Section through Frame.*

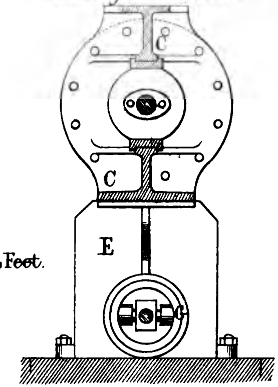
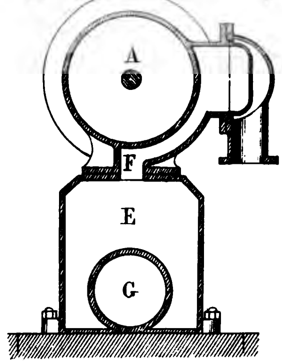


Fig. 4. *Transverse Section through Cylinder and Air pump.*



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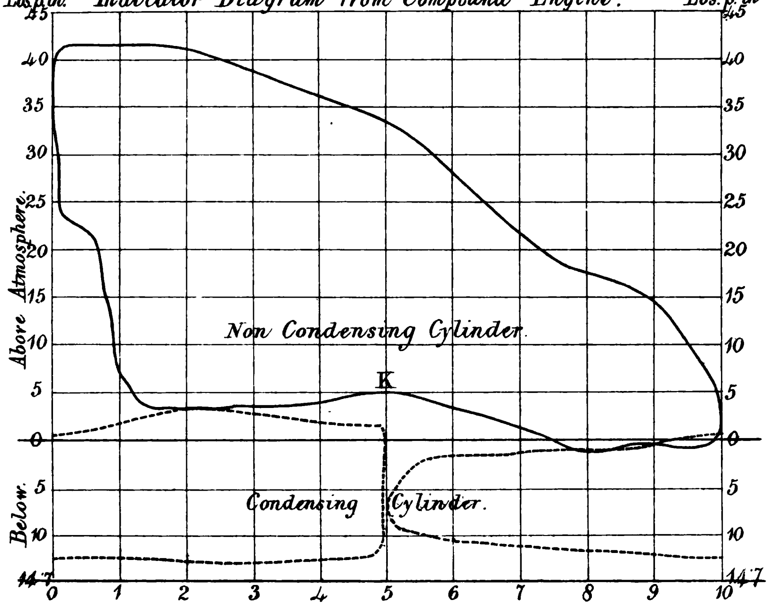
HORIZONTAL CONDENSING ENGINE.

Fig. 5.

Indicator Diagram from Compound Engine.



PISTON PACKING RINGS.